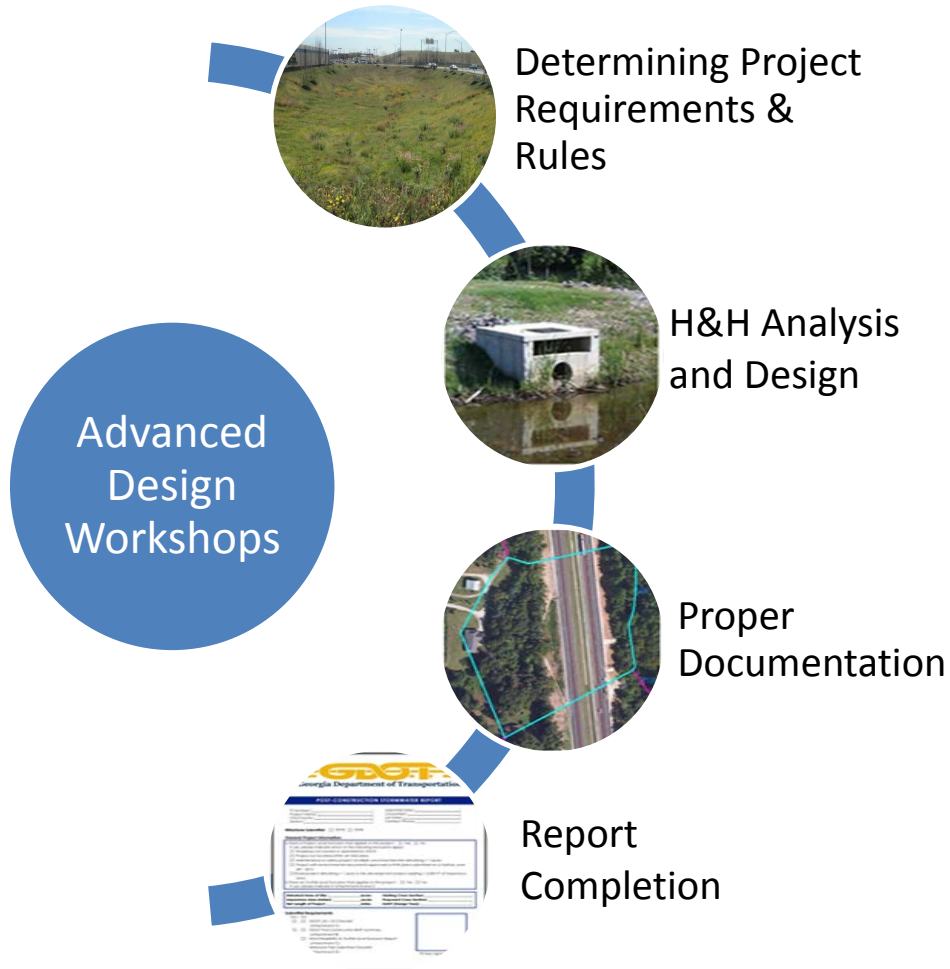


Advanced Design Workshops



1. **Stormwater Basics: Quality vs. Quantity**
2. **Downstream Analysis**
3. **Post-Construction BMP Exclusions and Infeasibilities**
4. **Wet Detention Pond Design**
5. **GDOT Post-Construction Stormwater Report**

More topics to come in 2017.....

Wet Detention Pond Design



Why Are We Here?

...to discuss wet detention ponds and how they are used to meet GDOT's post-construction BMP requirements



GDOT's Approved Post-Construction BMPs

Filter Strip

Grass Channel

Enhanced Swale

Infiltration Trench

Bioslope

Sand Filter

Bioretention Basin

Dry Detention Pond

Wet Detention Pond

Stormwater Wetland

Open Graded Friction
Course (OGFC)



Included in the designer's "tool box" to meet MS4 and other stormwater requirements.

Points of Discussion

Wet Detention Pond

- Function and Components
- Design Considerations
- Advantages and Disadvantages
- Sizing and Design Methodology



Wet Detention Pond

What is it?

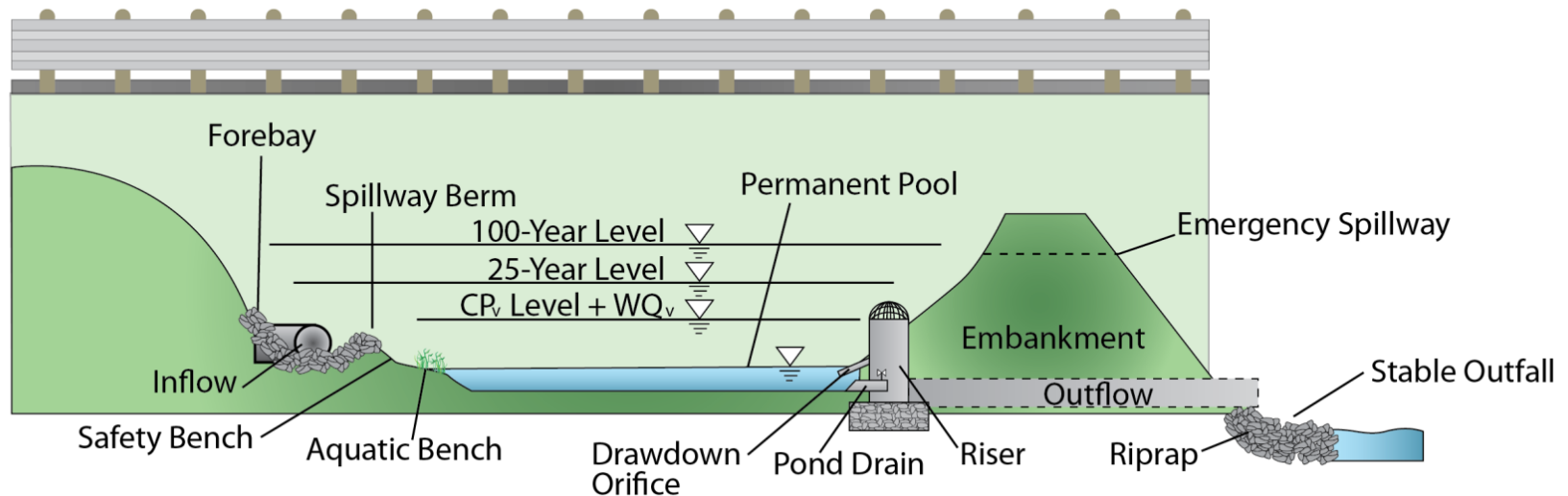
An earthen pond with a permanent pool and temporary storage for attenuating stormwater flows



Wet Detention Pond

What are its critical components?

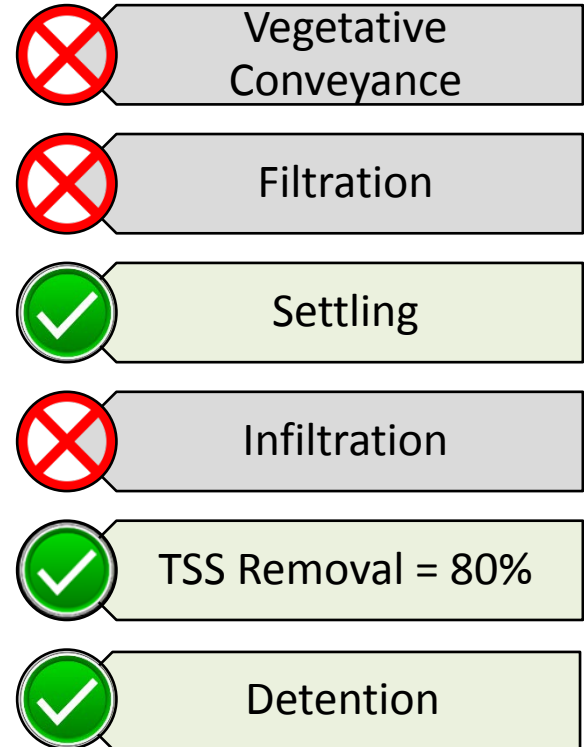
- Forebay
- Permanent Pool
- Aquatic Bench (wetland plantings)
- Safety Bench
- Detention Storage
- Outlet Control Structure
- Emergency Spillway



Wet Detention Pond

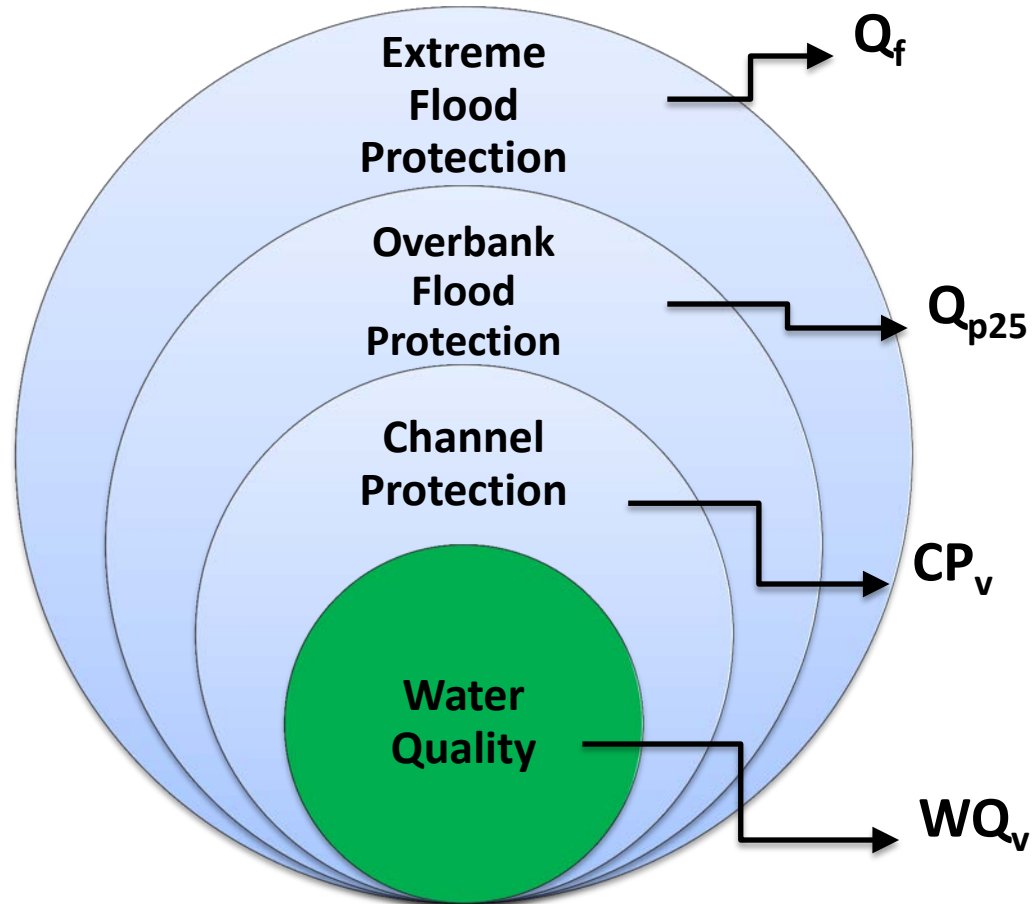
What is its purpose?

- Provide detention and attenuate peak flows
- Can be designed to meet all unified sizing criteria (water quality, channel protection, overbank flood protection and extreme flood protection)
- Reduce TSS and other pollutants



Wet Detention Pond

Four major Post-Construction Stormwater Management Requirements (MS4 permit):



Wet Detention Pond

Advantages

- Meets 80% TSS removal requirement
- Effective in treating other contaminants (fecal coliform, nitrogen, phosphorus, heavy metals)



Wet Detention Pond

Disadvantages

- Large footprint
- Difficult to maintain permanent pool
- Additional maintenance issues over dry pond
- Safety concerns associated with a permanent pool



Wet Detention Pond

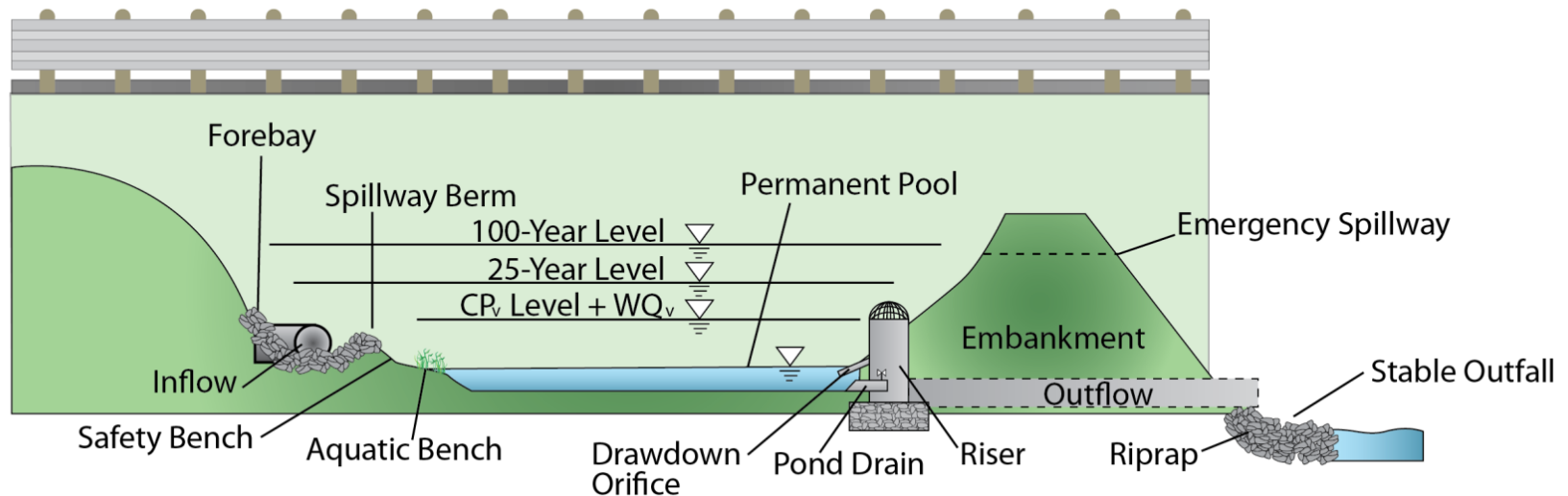
How does it compare to other BMPs?

BMP	TSS	Total Phosphorus	Total Nitrogen	Fecal Coliform	Metals
Filter Strip	60 %	20 %	20 %	-----	40 %
Grass Channel	50 %	25 %	20 %	-----	30 %
Enhanced Dry Swale	80 %	50 %	50 %	-----	40 %
Enhanced Wet Swale	80 %	25 %	40 %	-----	20 %
Infiltration Trench	80 %	60 %	60 %	90 %	90 %
Sand Filter	80 %	50 %	25 %	40 %	50 %
Dry Detention Basin	65 %	10 %	10 %	-----	50 %
Wet Detention Pond	80 %	50 %	30 %	70 %	50 %
Stormwater Wetland – Level I	80 %	40 %	30 %	70 %	50 %
Stormwater Wetland – Level II	85 %	75 %	55 %	85 %	60 %
Bioslope	95 %	80 %	25 %	60 %	85 %
OGFC	50 %	-----	-----	-----	-----
Bioretention	85 %	80 %	60 %	90 %	95 %

Wet Detention Pond

Design of Critical Components

- Forebay
- Permanent Pool
- Aquatic bench (wetland plantings)
- Safety Bench
- Detention Storage
- Outlet Control Structure
- Emergency Spillway

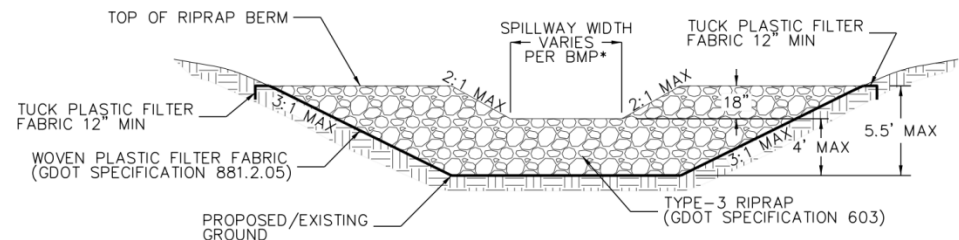


Wet Detention Pond

Forebay

Purpose: Dissipates inflow and reduces large particulates

Sizing: Capacity of 0.1 inch runoff/impervious acre



Wet Detention Pond

Permanent Pool

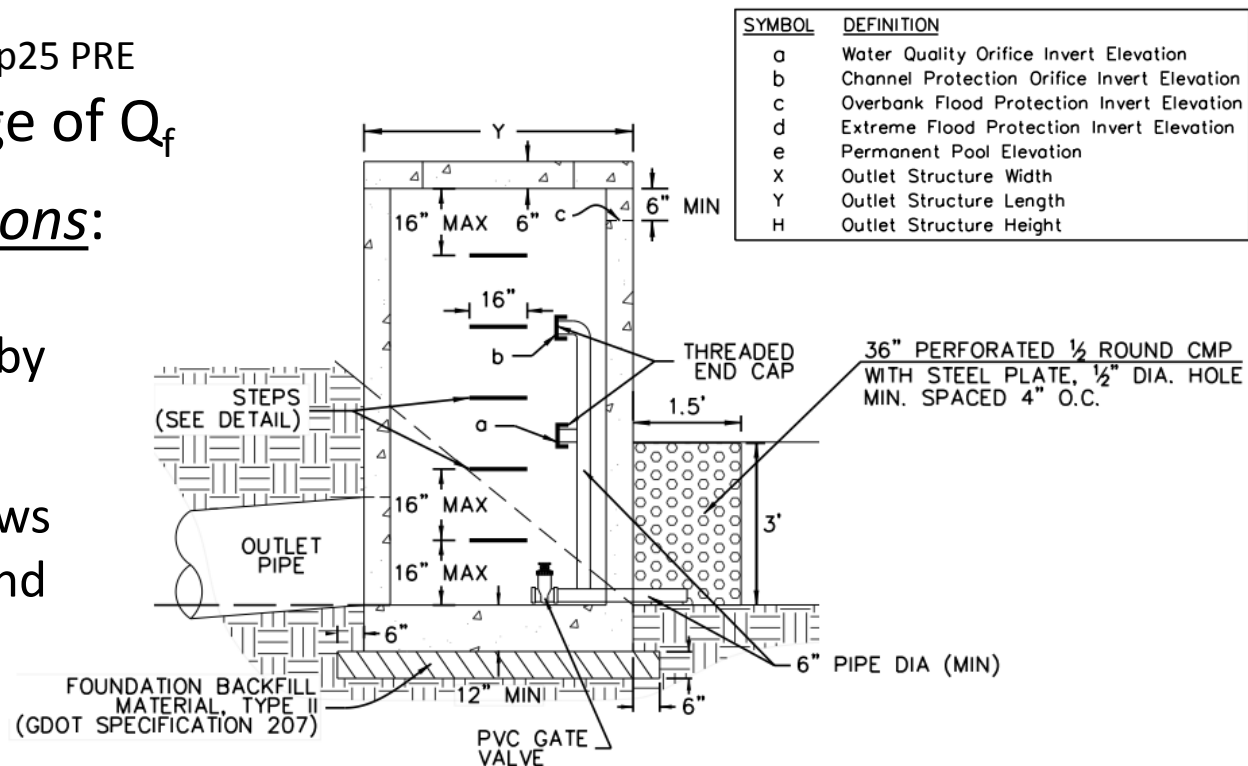
Purpose: Provides for settling and water quality treatment

Sizing: Capacity of 0.1 inch runoff/impervious acre or WQ_v for larger drainage areas

Design Considerations:

- Requires 3' to 8' depth (6' max is preferred for safety)
- Ensure permanent pool can be maintained with water balance calculation
- Bottom of pond should be minimum 2 ft above seasonably high water table if over a water supply aquifer





Wet Detention Pond

Detention Storage

Purpose: Detain and attenuate peak flows for larger storms

Sizing: Contain all Unified Sizing Criteria volumes (WQ_v , CP_v , Q_{p25} , Q_f)

Design Considerations:

- Drainage area between 10 and 75 acres
- Detention storage is located above (and does not include) permanent pool volume



Wet Detention Pond

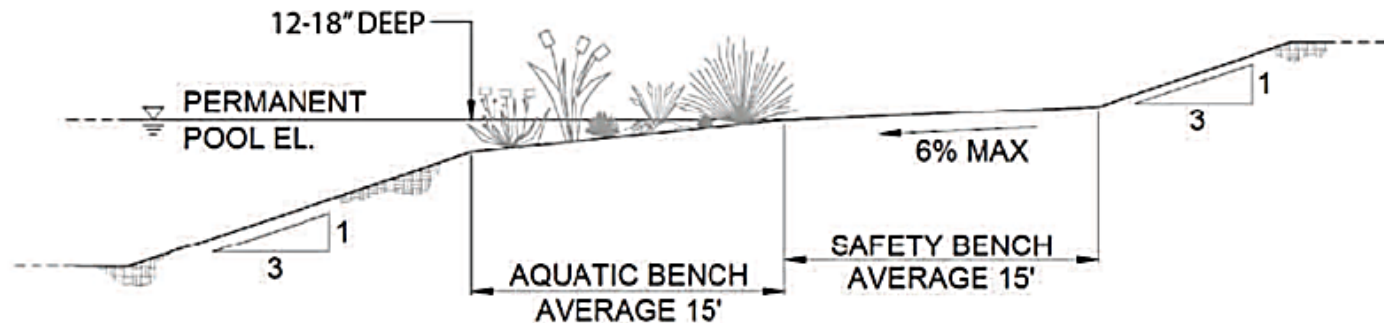
Embankment

Purpose: Provide aquatic and safety bench, maintenance access

Sizing: Bench/embankments to allow plantings and maintenance

Design Considerations:

- 2:1 maximum embankment side slope, but 3:1 is preferred
- 15' (average) aquatic bench with 12-18" depth below permanent pool
- 15' safety bench with maximum 6% slope (not required if embankment slope 4:1 or less)



Wet Detention Pond

Emergency Spillway

Purpose: Provide emergency overflow relief for protection of pond structural integrity and downstream flood prevention during extreme events

Sizing: Size to safely pass the 100-yr peak flow

Design Considerations:

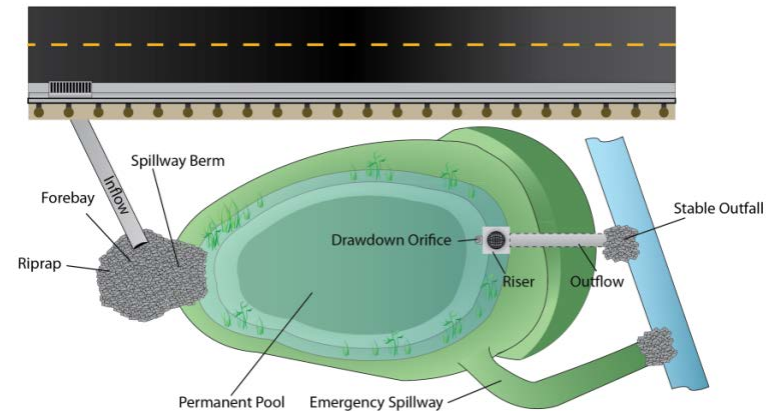
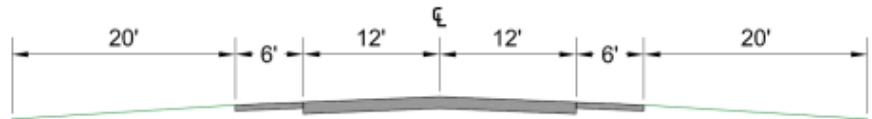
- Protect and armor spillway weir and embankment tie-ins with concrete or riprap
- Proper sizing and protection of conveyance connection to stable outfall



Design Example

Given:

- New alignment roadway project in Paulding County (District 6)
- Total drainage area of 10.23 acres discharging into a wet detention pond comprised of:
 - 3,000 linear feet of roadway:
 - two 12-ft lanes
 - two 6-ft paved shoulders
 - 20-ft grassed areas (both sides of road) draining via sheet flow
 - 5 acres off-site drainage area (no existing impervious area)
 - Pre developed $T_c = 45$ minutes
 - Post developed $T_c = 25$ minutes



Steps to Design Wet Detention Pond

1

Calculate forebay volume

2

Calculate permanent pool volume and min depth

3

Calculate water quality volume and design orifice

4

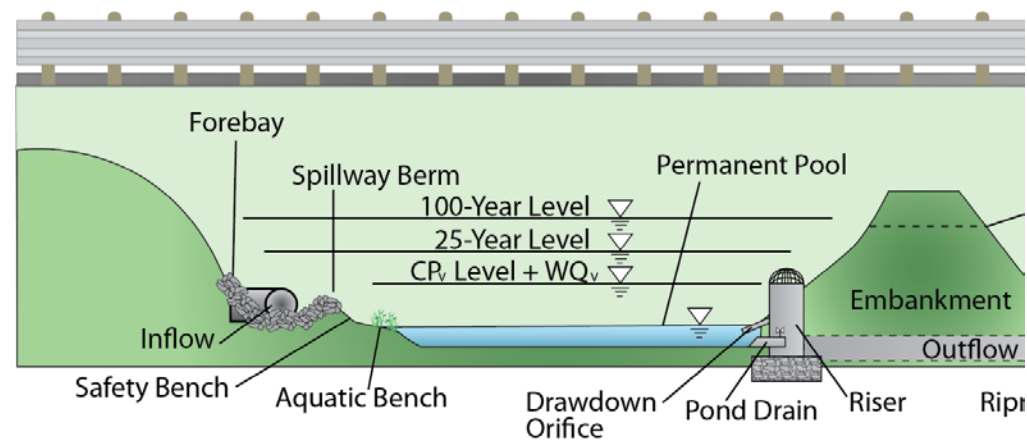
Calculate channel protection volume and design orifice

5

Design pond and outlet to maintain 25-yr pre-development peak flow

6

Design spillway to safely convey 100-yr post-development peak flow



Steps to Design Wet Detention Pond

1 Calculate Forebay Volume

Minimum forebay size: 0.1 inch per impervious acre (ImpAc)

$$\text{ImpAc} = (3000') * (24' + 12') = 108,000 \text{ ft}^2 = 2.48 \text{ acres}$$

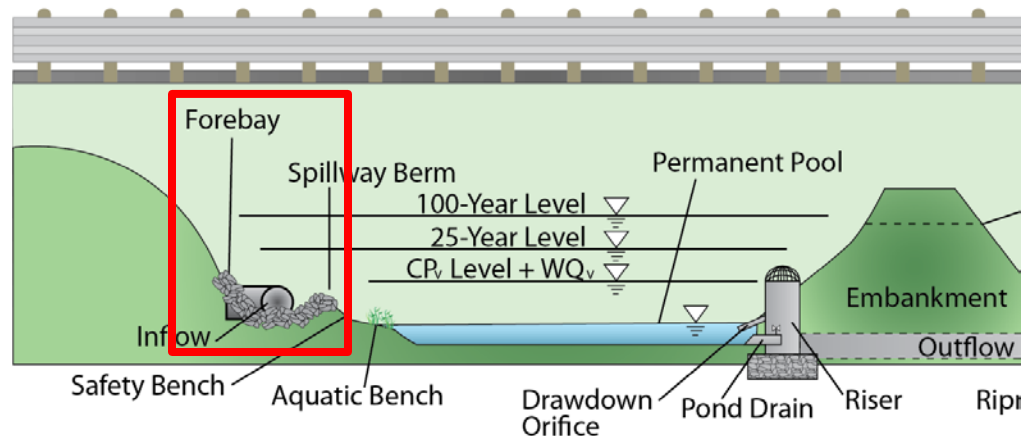
$$V_{\text{Forebay}} = (0.1 \text{ inch/acre}) * (2.48 \text{ acre}) = .248 \text{ acre-inch}$$

$$= 900 \text{ ft}^3 \text{ (actual forebay volume} = 1,046 \text{ ft}^3)$$

Conversions:

$$1 \text{ acre} = 43,560 \text{ ft}^2$$

$$1 \text{ acre-inch} = 3,630 \text{ ft}^3$$



Steps to Design Wet Detention Pond

- 1 Calculate forebay volume $V_{\text{forebay}} = 1,046 \text{ ft}^3$
- 2 Calculate permanent pool volume and verify pond can maintain
- 3 Calculate water quality volume and design orifice
- 4 Calculate channel protection volume and design orifice
- 5 Design pond and outlet to maintain 25-yr pre-development peak flow
- 6 Design spillway to safely convey 100-yr post-development peak flow

Steps to Design Wet Detention Pond

2 Calculate permanent pool volume

Minimum permanent pool (PP) size: 0.1 inch per impervious acre

$$\text{ImpAc} = (3000') * (24' + 12') = 108,000 \text{ ft}^2 = 2.48 \text{ acres}$$

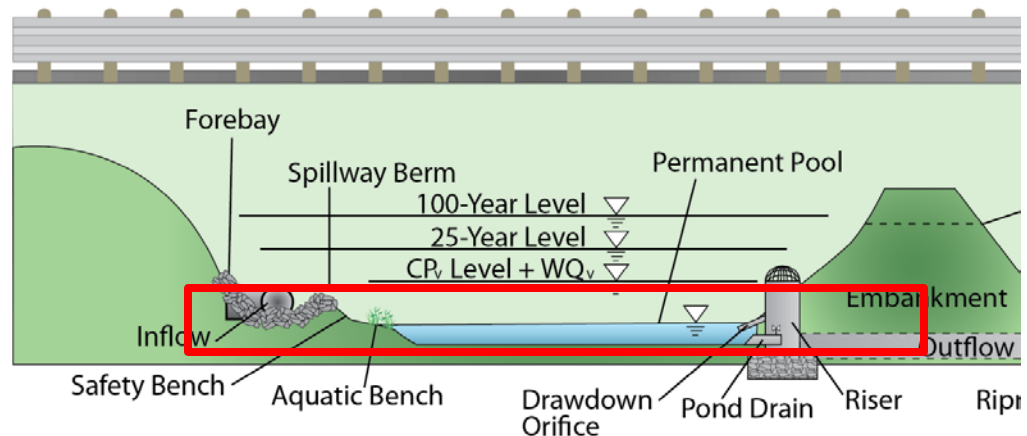
$$V_{pp} = (0.1 \text{ inch/acre}) * (2.48 \text{ acre}) = .248 \text{ acre-inch}$$

$$= 900 \text{ ft}^3 \text{ (actual permanent pool = 1,422 ft}^3\text{)}$$

Conversions:

$$1 \text{ acre} = 43,560 \text{ ft}^2$$

$$1 \text{ acre-inch} = 3,630 \text{ ft}^3$$



Water Balance Calculations

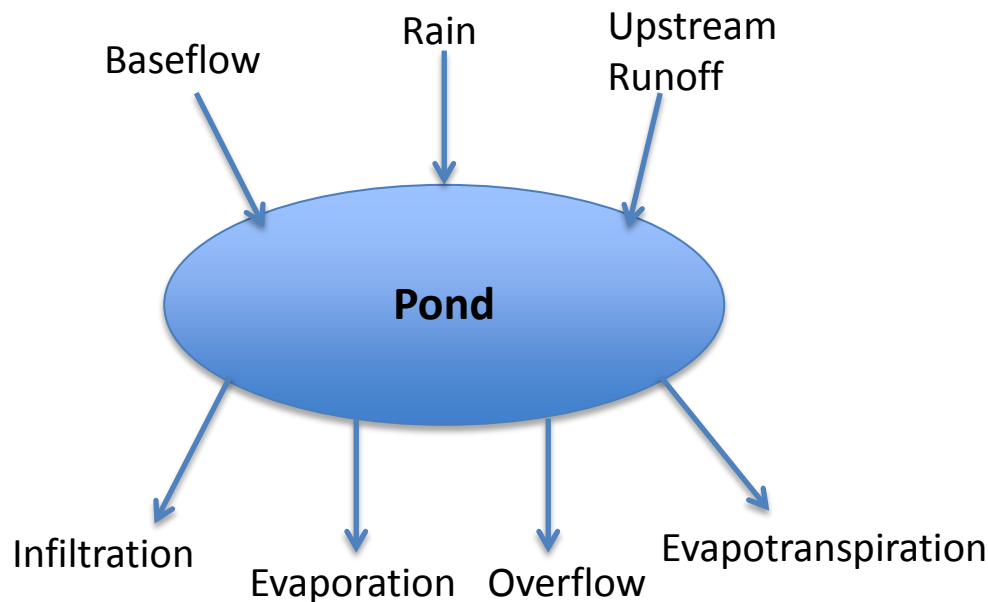
2 Verify perm pool can be maintained

$$\Delta V = \Sigma \text{inflow} - \Sigma \text{outflow}$$

Eq 10.2-1

$$\Delta V = P + Ro + Bf - I - E - Et - Of$$

Eq 10.2-2



P = precipitation (ft)
 Ro = runoff (ac-ft)
 Bf = baseflow (ac-ft)
 I = infiltration (ft)
 E = evaporation (ft)
 Et = evapotranspiration (ft)
 Of = overflow (ac-ft)

*For this example, assume no baseflow and no evapotranspiration. Overflow is not a concern for average values of precipitation.

Water Balance Calculation Steps

1

Calculate the volume of precipitation that falls on the permanent pool

4

Calculate infiltration

2

Calculate the volume of runoff from the contributing drainage area

5

Calculate the difference between the inflows and outflows

SUM INFLOWS

SUM OUTFLOWS

3

Calculate the volume of evaporation that occurs over the permanent pool

**VERIFY PERM POOL CAN
BE MAINTAINED**

Water Balance Calculations

1

Calculate the volume of precipitation that falls on the permanent pool

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precip (in)	4.84	5.16	5.08	3.94	4.13	4.06	5.12	4.33	4.09	3.43	4.29	4.49



U.S. climate data

Temperature - Precipitation - Sunshine - Snowfall

Home United States Georgia

Monthly Daily History Geo & Map Weather Forecast

Climate Dallas - Georgia

°C | °F

	Jan	Feb	Mar	Apr	May	Jun
Average high in °F:	51	56	64	73	80	87
Average low in °F:	30	33	39	46	55	64
Av. precipitation in inch:	4.84	5.16	5.08	3.94	4.13	4.06
Days with precipitation:	-	-	-	-	-	-
Hours of sunshine:	-	-	-	-	-	-
Average snowfall in inch:	1	1	1	0	0	0

	Jul	Aug	Sep	Oct	Nov	Dec
Average high in °F:	89	89	83	73	64	53
Average low in °F:	67	67	60	48	39	32
Av. precipitation in inch:	5.12	4.33	4.09	3.43	4.29	4.49
Days with precipitation:	-	-	-	-	-	-

<http://www.usclimatedata.com/climate/dallas/georgia/united-states/usga0157>

Water Balance Calculations

1

Calculate the volume of precipitation that falls on the permanent pool

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precip (in)	4.84	5.16	5.08	3.94	4.13	4.06	5.12	4.33	4.09	3.43	4.29	4.49
P (pool) (ac-ft)	0.008	0.009	0.008	0.007	0.007	0.007	0.009	0.007	0.007	0.006	0.007	0.007

Precipitation volume directly into pond (P) equals precipitation depth (inches) times permanent pool surface area (**0.02 acre**) divided by 12 to convert to acre-feet

Water Balance Calculations

2

Calculate the volume of runoff from the contributing drainage area

$$Ro = \frac{QA}{12} \quad \text{Eq 10.2-5}$$

$$Q = (0.9R_v)P \quad \text{Eq 10.2-4}$$

$$Ro = \frac{(0.9R_v) * P * A}{12}$$

Q = runoff depth (in)

Ro = runoff volume (ac-ft)

A = site area minus permanent pool area (acres)

P = precipitation (in)

R_v = volumetric runoff coefficient

Values needed to calculate Ro :

$R_v = ?$

P = determined in previous step

$A = ?$

Water Balance Calculations

2

Calculate the volume of runoff from the contributing drainage area

*I = percent imperviousness
of drainage basin (percent)*

$$R_v = 0.05 + 0.009(I) \quad \text{Eq 10.2-3}$$

$$I = \frac{2.48 \text{ ac}}{10.23 \text{ ac}} = 24.2\%$$

$$R_v = 0.05 + 0.009(24.2) = 0.27$$

Water Balance Calculations

2

Calculate the volume of runoff from the contributing drainage area

Permanent Pool Area = $857 \text{ ft}^2 = 0.02 \text{ acre}$

Basin Area = 10.23 acres

$A = 10.23 - 0.02 = 10.21 \text{ acres}$

$$Ro = \frac{(0.9 * 0.27) * P * (10.21 \text{ ac})}{12 \left(\frac{\text{in}}{\text{ft}}\right)}$$

Conversions:

$1 \text{ acre} = 43,560 \text{ ft}^2$

Water Balance Calculations

2

Calculate the volume of runoff from the contributing drainage area

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precip (in)	4.84	5.16	5.08	3.94	4.13	4.06	5.12	4.33	4.09	3.43	4.29	4.49
P (pool) (ac-ft)	0.008	0.009	0.008	0.007	0.007	0.007	0.009	0.007	0.007	0.006	0.007	0.007
Ro (ac-ft)	1.00	1.07	1.05	0.81	0.85	0.84	1.06	0.90	0.85	0.71	0.89	0.93

Water Balance Calculations

Total the inflow to the Wet Pond

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
P (pool) (ac-ft)	0.008	0.009	0.008	0.007	0.007	0.007	0.009	0.007	0.007	0.006	0.007	0.007
Ro (ac-ft)	1.00	1.07	1.05	0.81	0.85	0.84	1.06	0.90	0.85	0.71	0.89	0.93
Inflow (ac-ft)	1.008	1.079	1.058	0.817	0.857	0.847	1.069	0.907	0.857	0.716	0.897	0.937

Sum the monthly precipitation and runoff inflows to get total monthly inflow to the pond

Water Balance Calculations

3

Calculate the volume of evaporation that occurs over the permanent pool

- Obtain monthly evaporation distribution

Table 10.2-2 Evaporation Monthly Distribution (10-11)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
3.2%	4.4%	7.4%	10.3%	12.3%	12.9%	13.4%	11.8%	9.3%	7.0%	4.7%	3.2%

- Determine the annual free water surface evaporation value
= 37.5 inches

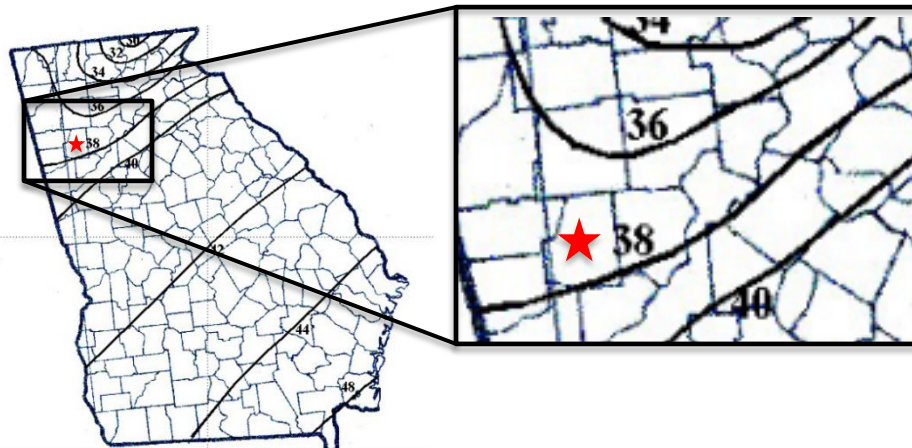


Figure 3.1.B-1 Average Annual Free Water Surface Evaporation (in inches)
(Source: NOAA, 1982)

Fig 10.2-3

Water Balance Calculations

3

Calculate the volume of evaporation that occurs over the permanent pool

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Evap. Dist.	3.2%	4.4%	7.4%	10.3%	12.3%	12.9%	13.4%	11.8%	9.3%	7.0%	4.7%	3.2%
E (inch)	1.2	1.7	2.8	3.9	4.6	4.8	5.0	4.4	3.5	2.6	1.8	1.2
E (ac-ft)	0.002	0.003	0.005	0.006	0.008	0.008	0.008	0.007	0.006	0.004	0.003	0.002

Evaporation equals monthly percent of 37.5 inches multiplied by the surface area of the permanent pool (*calculated earlier as .02 acre*) and converted to acre-feet

Water Balance Calculations

4

Calculate the volume of infiltration that occurs in the wet pond

Estimate the hydraulic conductivity of your soils using Table 10.2-1

For this example, assume sandy clay loam soil

Table 10.2-1 Saturated Hydraulic Conductivity ⁽¹⁰⁻¹¹⁾

Material	Hydraulic Conductivity	
	in/hr	ft/day
ASTM Crushed Stone No. 3	50,000	100,000
ASTM Crushed Stone No. 4	40,000	80,000
ASTM Crushed Stone No. 5	25,000	50,000
ASTM Crushed Stone No. 6	15,000	30,000
Sand	8.27	16.54
Loamy sand	2.41	4.82
Sandy loam	1.02	2.04
Loam	0.52	1.04
Silt loam	0.27	0.54
Sandy clay loam	0.17	0.34
Clay loam	0.09	0.18
Silty clay loam	0.06	0.12
Sandy clay	0.05	0.1
Silty clay	0.04	0.08
Clay	0.02	0.04

Water Balance Calculations

4

Calculate the volume of infiltration that occurs in the wet pond

$$I = Ak_h G_h \quad \text{Eq 10.2-6}$$

I = infiltration (ac-ft/day)

A = cross sectional area through which water infiltrates (ac).

k_h = saturated hydraulic conductivity or infiltration rate (ft/day)

G_h = hydraulic gradient = pressure head/distance

In this example, we have a total surface area of 0.02 acres (A_{total}) in our permanent pool.

Typical values of G_h are 1.0 for pond bottom and 0.5 for pond sides steeper than 4:1

$$A_{\text{total}} = A_{\text{bottom}} + A_{\text{sides}} = 0.016 + 0.004$$

$$\begin{aligned} I &= [(0.004 \text{ ac})(1) + (0.016 \text{ ac})(0.5)] \left(0.34 \frac{\text{ft}}{\text{day}} \right) \\ &= 0.004 \text{ ac} - \text{ft/day} \end{aligned}$$

Water Balance Calculations

4

Calculate the volume of infiltration that occurs in the wet pond

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Days/ Mo	31	28	31	30	31	30	31	31	30	31	30	31
Evap. Dist.	3.2%	4.4%	7.4%	10.3%	12.3%	12.9%	13.4%	11.8%	9.3%	7.0%	4.7%	3.2%
E (inch)	1.2	1.7	2.8	3.9	4.6	4.8	5.0	4.4	3.5	2.6	1.8	1.2
E (ac-ft)	0.002	0.003	0.005	0.006	0.008	0.008	0.008	0.007	0.006	0.004	0.003	0.002
I (ac-ft)	0.105	0.095	0.105	0.102	0.105	0.102	0.105	0.105	0.102	0.105	0.102	0.105

Infiltration equals daily infiltration rate of .004 ac-ft per day multiplied by the number of days in each month

Water Balance Calculations

Total the outflow from the Wet Pond

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
E (ac-ft)	0.002	0.003	0.005	0.006	0.008	0.008	0.008	0.007	0.006	0.004	0.003	0.002
I (ac-ft)	0.105	0.095	0.105	0.102	0.105	0.102	0.105	0.105	0.102	0.105	0.102	0.105
Outflow (ac-ft)	0.107	0.098	0.110	0.108	0.113	0.110	0.114	0.113	0.108	0.110	0.105	0.107

Sum the monthly evaporation and infiltration outflows to get total monthly outflow from the pond

Water Balance Calculations

5

Calculate the difference between the inflows and outflows

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Inflow (ac-ft)	1.008	1.079	1.058	0.817	0.857	0.847	1.069	0.907	0.857	0.716	0.897	0.937
Outflow (ac-ft)	0.107	0.098	0.110	0.108	0.113	0.110	0.114	0.113	0.108	0.110	0.105	0.107
Balance (ac-ft)	0.901	0.981	0.948	0.709	0.744	0.737	0.955	0.794	0.749	0.606	0.792	0.83
Balance (ft ³)	39,248	42,732	41,295	30,884	32,409	32,104	41,600	34,587	32,626	26,397	34,500	36,155

Subtract the outflows from the inflows to get the monthly balance of the wet pond and convert to cubic feet for comparison with perm pool volume

The water balance is greater than the permanent pool volume (1,422 ft³) every month: **the pond can maintain the permanent pool**

Steps to Design Wet Detention Pond

1

Calculate forebay volume

$$V_{\text{forebay}} = 1,046 \text{ ft}^3$$

2

Calculate permanent pool volume and verify pond can maintain

$$V_{\text{permpool}} = 1,422 \text{ ft}^3, \text{Depth}_{\text{min}} = 3.0 \text{ ft}$$

3

Calculate water quality volume and design orifice

4

Calculate channel protection volume and design orifice

5

Design pond and outlet to maintain 25-yr pre-development peak flow

6

Design spillway to safely convey 100-yr post-development peak flow

Steps to Design Wet Detention Pond

3 Calculate water quality volume (WQ_v)

WQ_v based on basin area and new impervious area percentage

Eq 10.2-7 $WQ_v \text{ (ft}^3\text{)} = 1.2_{\text{(in)}} * R_v * A_{\text{(acres)}} * 43,560_{\text{(acres/ft}^2\text{)}} / 12_{\text{(in/ft)}}$

$$= (1.2) * (0.47) * (5.23) * (43,560) / 12$$

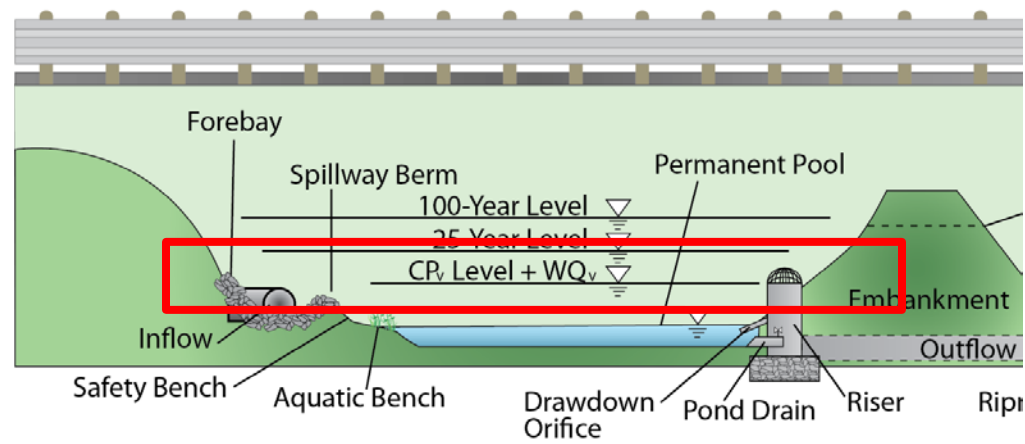
$$= \mathbf{10,707 \text{ ft}^3}$$

R_v = volumetric runoff coefficient
 $= 0.05 + 0.009 * I$
 $= 0.05 + 0.009 * (47) = 0.47$
 I = impervious area (%)

Remember the permanent pool volume is included in WQ_v , so:

$$WQ_v \text{ (ft}^3\text{)} = 10,707 \text{ ft}^3 - (1,046 \text{ ft}^3 + 1,422 \text{ ft}^3)$$

$$= \mathbf{8,239 \text{ ft}^3}$$



Steps to Design Wet Detention Pond

3 Design water quality (WQ_v) orifice

Orifice sized to release WQ_v over 24 hours

Orifice Equation:

$$Q_{WQ_v} \text{ (cfs)} = C_D * A \text{ (ft}^2\text{)} * \sqrt{(2g)\Delta H_{\max} \text{ (ft)}}$$

Eq 10.4.3-3

$$(.095 \text{ cfs}) = (0.6) * (A) * \sqrt{2 * (32.2 \text{ ft/s}^2) * (1 \text{ ft})}$$

$$A = .020 \text{ ft}^2$$

$$D = \sqrt{4 * (.020 \text{ ft}^2) / \pi}$$

$$D = 0.16 \text{ ft} = 1.9 \text{ in (use 2.0 inches for constructability)}$$

Q_{WQ_v} (orifice flow rate) = 8,239 ft³/24 hr = 0.095 cfs

C_D (orifice coefficient) = 0.6

A = orifice area (ft²)

ΔH_{\max} (max depth at WQ_v stage) = 1.0 ft

WQ_v orifice: 2" diameter at top of permanent pool

Steps to Design Wet Detention Pond

1

Calculate forebay volume

$$V_{\text{forebay}} = 1,046 \text{ ft}^3$$

2

Calculate permanent pool volume and verify pond can maintain

$$V_{\text{permpool}} = 1,422 \text{ ft}^3, \text{Depth}_{\text{min}} = 3.0 \text{ ft}$$

3

Calculate water quality volume and design orifice

$$WQ_v = 8,239 \text{ ft}^3, D_{\text{orif}} = 2'' , \text{Elev}_{\text{orif}} = \text{perm pool elevation}$$

4

Calculate channel protection volume and design orifice

5

Design pond and outlet to maintain 25-yr pre-development peak flow

6

Design spillway to safely convey 100-yr post-development peak flow

Channel Protection Volume (CP_v) Calculation Steps

1

Determine runoff depth(Q -inches) for 1-year 24-hour storm event

2

Determine the unit peak discharge rate (q_u) for the 1-year 24-hour storm event

3

Compute the channel protection volume

Channel Protection Volume (CP_v) Calculation Steps

1

Determine direct runoff depth for 1-year 24-hour storm event

Calculate direct runoff:

P = 1-year 24-hour rainfall depth (inches)

S = ultimate abstraction (inches)

$$Q_{1,24} = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

Eq 10.2-10

S = 4.29 inches

P = ?

To calculate S, we use the following formula:

$$S = \frac{1000}{CN} - 10$$

Eq 10.2-11

We need to know the basin CN to perform this calculation

Channel Protection Volume (CP_v) Calculation Steps

1

Determine direct runoff depth for 1-year 24-hour storm event

Calculate composite CN number for the project basin:

Impervious Area (*calculated earlier*) = 2.48 ac (CN=98)

Pervious Area (10.23 total acres – 2.48 acres) = 7.75 ac (CN=61)

$$CN = \frac{(2.48 \times 98) + (7.75 \times 61)}{10.23} = 70$$

Now we can calculate ultimate abstraction:

$$S = \frac{1000}{CN} - 10 = 1000/70 - 10 = \mathbf{4.29 \text{ inches}}$$

S = 4.29 inches
P = ?

Channel Protection Volume (CP_v) Calculation Steps

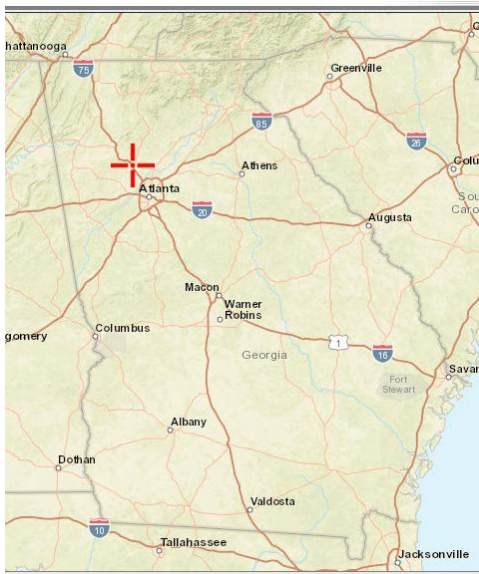
1

Determine direct runoff depth for 1-year 24-hour storm event

Obtain 1-year 24-hour rainfall depth for project location from NOAA website:

http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=ga

$S = 4.29$ inches
 $P = 3.41$ inches



PDS-based precipitation frequency estimates with 90% confidence intervals (in inches) ¹									
Duration	Average recurrence interval (years)								
	1	2	5	10	25	50	100	200	500
5-min	0.410 (0.351-0.483)	0.470 (0.402-0.555)	0.576 (0.490-0.680)	0.669 (0.565-0.793)	0.806 (0.660-0.987)	0.919 (0.731-1.13)	1.04 (0.794-1.30)	1.17 (0.850-1.49)	1.34 (0.937-1.75)
10-min	0.601 (0.513-0.708)	0.689 (0.588-0.812)	0.843 (0.717-0.996)	0.979 (0.828-1.16)	1.18 (0.966-1.45)	1.35 (1.07-1.66)	1.52 (1.16-1.91)	1.71 (1.24-2.19)	1.97 (1.37-2.57)
15-min	0.732 (0.626-0.863)	0.840 (0.717-0.991)	1.03 (0.874-1.21)	1.19 (1.01-1.42)	1.44 (1.18-1.76)	1.64 (1.31-2.03)	1.85 (1.42-2.33)	2.08 (1.52-2.66)	2.40 (1.67-3.13)
30-min	1.04 (0.889-1.23)	1.19 (1.02-1.41)	1.46 (1.24-1.72)	1.69 (1.43-2.01)	2.05 (1.67-2.51)	2.33 (1.86-2.88)	2.64 (2.02-3.32)	2.97 (2.17-3.80)	3.43 (2.39-4.48)
60-min	1.35 (1.15-1.59)	1.54 (1.32-1.82)	1.89 (1.61-2.23)	2.19 (1.85-2.60)	2.65 (2.17-3.24)	3.02 (2.40-3.73)	3.42 (2.61-4.29)	3.84 (2.80-4.92)	4.44 (3.10-5.80)
2-hr	1.66 (1.42-1.94)	1.90 (1.63-2.22)	2.32 (1.98-2.72)	2.69 (2.29-3.17)	3.25 (2.68-3.95)	3.71 (2.98-4.54)	4.19 (3.24-5.23)	4.72 (3.48-5.99)	5.45 (3.86-7.05)
3-hr	1.86 (1.61-2.17)	2.13 (1.83-2.48)	2.60 (2.23-3.03)	3.01 (2.57-3.53)	3.62 (3.00-4.38)	4.13 (3.33-5.03)	4.66 (3.62-5.78)	5.23 (3.89-6.60)	6.03 (4.30-7.76)
6-hr	2.30 (1.99-2.66)	2.61 (2.26-3.03)	3.16 (2.72-3.66)	3.63 (3.12-4.23)	4.33 (3.62-5.19)	4.91 (3.99-5.92)	5.51 (4.33-6.76)	6.15 (4.63-7.69)	7.04 (5.10-8.97)
12-hr	2.85 (2.48-3.27)	3.22 (2.80-3.70)	3.85 (3.34-4.44)	4.40 (3.80-5.08)	5.19 (4.35-6.15)	5.82 (4.77-6.95)	6.48 (5.14-7.87)	7.17 (5.47-8.86)	8.12 (5.96-10.2)
24-hr	3.41 (2.99-3.89)	3.88 (3.40-4.43)	4.66 (4.06-5.33)	5.31 (4.61-6.09)	6.23 (5.25-7.29)	6.94 (5.73-8.20)	7.67 (6.14-9.21)	8.41 (6.49-10.3)	9.41 (7.01-11.7)
2-day	3.93 (3.46-4.45)	4.52 (3.97-5.12)	5.47 (4.80-6.21)	6.26 (5.47-7.13)	7.35 (6.23-8.52)	8.18 (6.81-9.58)	9.02 (7.29-10.7)	9.86 (7.70-11.9)	11.0 (8.30-13.5)

Channel Protection Volume (CP_v) Calculation Steps

1

Determine direct runoff depth for 1-year 24-hour storm event

Now we have values for S and P:

Calculate direct runoff:

P = 1-year 24-hour rainfall depth (inches)
S = ultimate abstraction (inches)

$$Q_{1,24} = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

Eq 10.2-10

S = 4.29 inches
P = 3.41 inches

$$= \frac{(3.41 - 0.2 * 4.29)^2}{(3.41 + 0.8 * 4.29)}$$

= 0.95 inches

Channel Protection Volume (CP_v) Calculation Steps

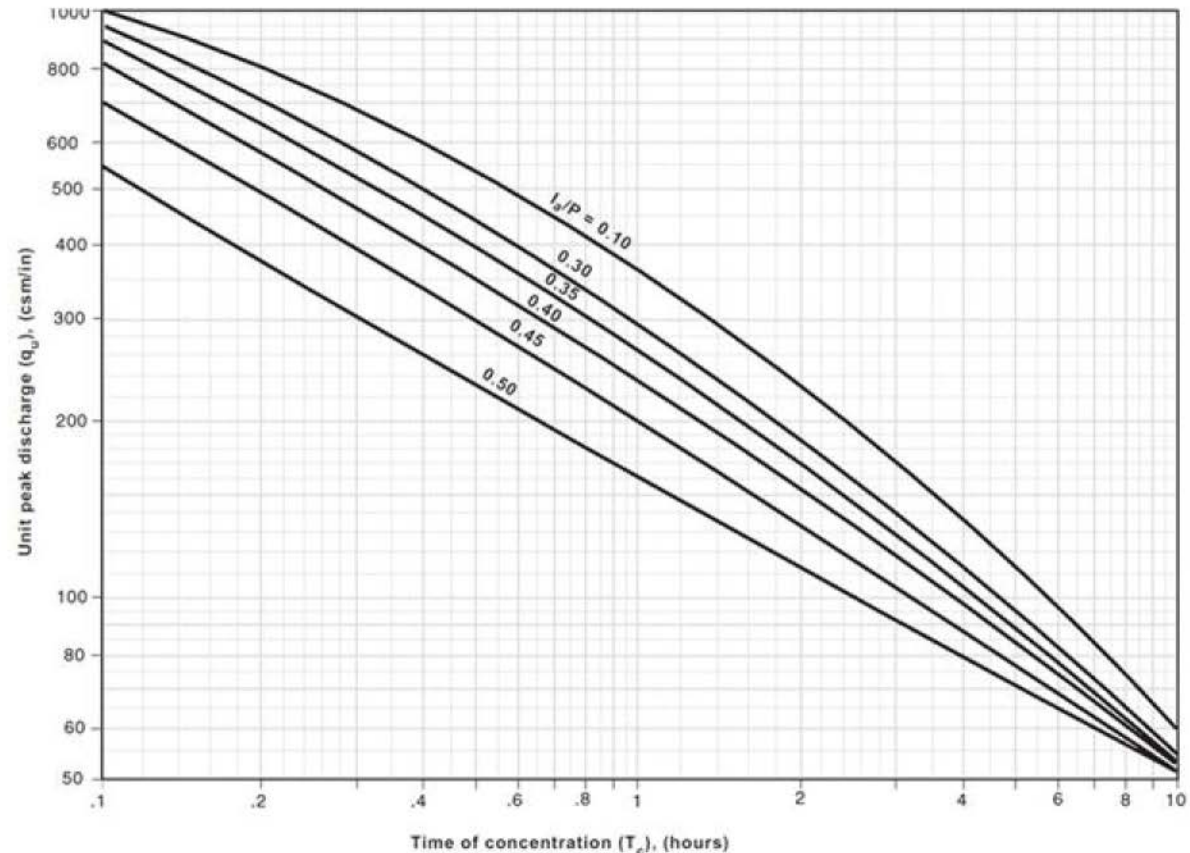
2

Determine the unit peak discharge rate (q_u) for the 1-year 24-hour storm event

Determine q_u :

Figure 10.2-8 - Unit peak discharge (q_u) for SCS Type II rainfall distribution (10-33)

Fig 10.2-8



$I_a = ?$
 $P = 3.41$ inches
 $T_c = 25$ minutes (*given*)

$$I_a = 0.2 * S$$

$$= 0.2 * 4.29 \text{ inches}$$

$$= 0.858 \text{ inches}$$

Channel Protection Volume (CP_v) Calculation Steps

2

Determine the unit peak discharge rate (q_u) for the 1-year 24-hour storm event

Determine q_u :

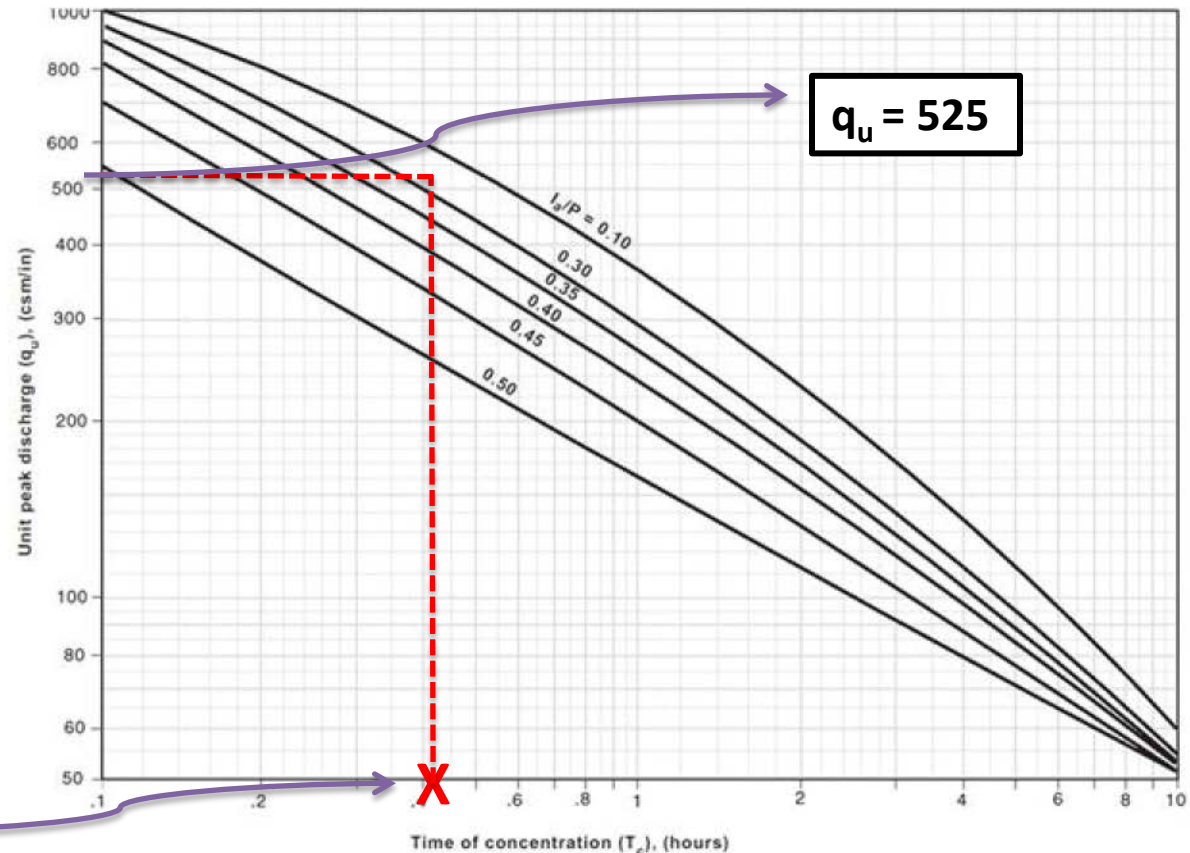
Figure 10.2-8 - Unit peak discharge (q_u) for SCS Type II rainfall distribution (10-33)

Fig 10.2-8

$I_a = 0.858$
 $P = 3.41$ inches
 $T_c = 25$ minutes (given)

$$I_a/P = 0.858/3.41 \\ = 0.25$$

$$T_c = 25 \text{ minutes} \\ = 0.42 \text{ hour}$$



Channel Protection Volume (CP_v) Calculation Steps

3 Compute the channel protection volume

Calculate V_s (storage volume required):

Eq 10.2-13

$$V_S = \left(\frac{V_S}{V_R} \right) * Q^{1.24} * A * 3630$$

We need to know V_S/V_R to perform this calculation.....

Eq 10.2-12

$$\frac{V_S}{V_R} = 0.682 - 1.43 \left(\frac{q_o}{q_i} \right) + 1.64 \left(\frac{q_o}{q_i} \right)^2 - 0.804 \left(\frac{q_o}{q_i} \right)^3$$

We need to know q_o/q_i to perform this calculation.....

Channel Protection Volume (CP_v) Calculation Steps

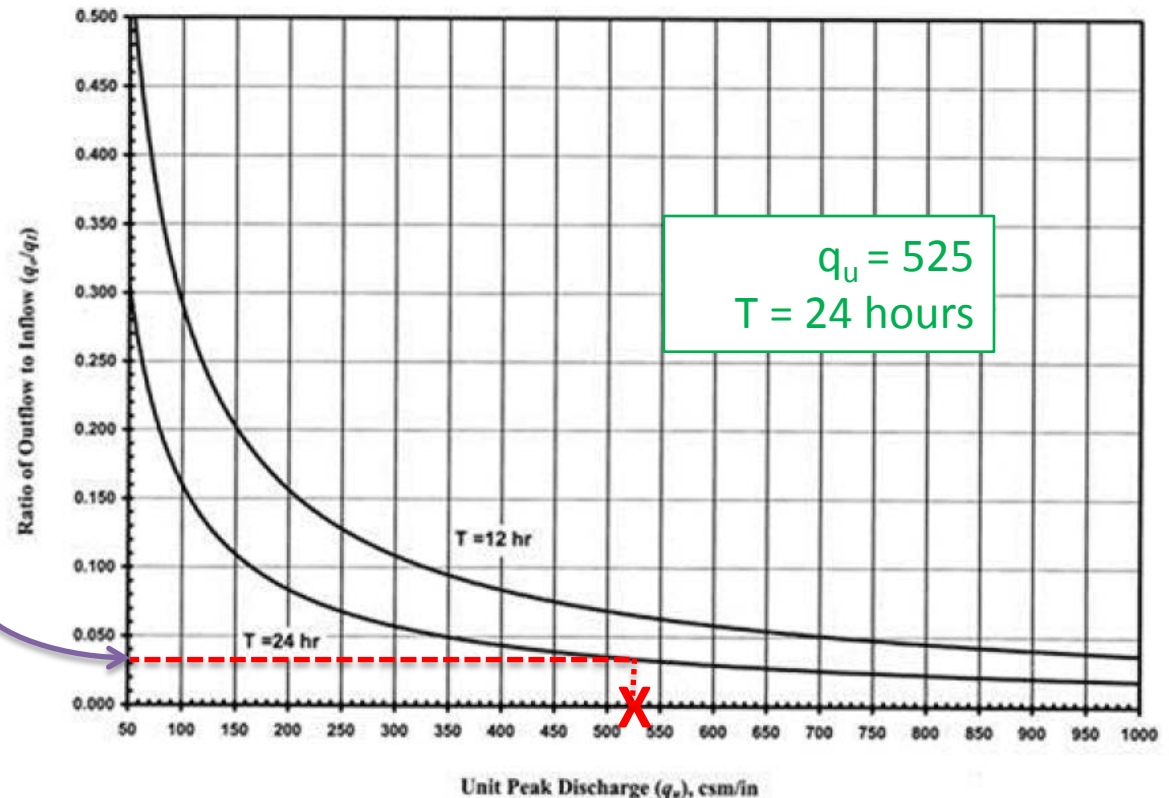
3 Compute the channel protection volume

Determine q_o/q_i :

Fig 10.2-8

$q_o/q_i = .035$

Figure 10.2-6 - SCS ratio of outflow to inflow curves (10-23)



Channel Protection Volume (CP_v) Calculation Steps

3 Compute the channel protection volume

Now we can calculate V_s/V_R :

Eq 10.2-12

$$\frac{V_s}{V_R} = 0.682 - 1.43 \left(\frac{q_o}{q_i} \right) + 1.64 \left(\frac{q_o}{q_i} \right)^2 - 0.804 \left(\frac{q_o}{q_i} \right)^3$$

$q_o/q_i = .035$

$$\begin{aligned} &= 0.682 - 1.43 (.035) + 1.64 (.035)^2 - 0.804 (.035)^3 \\ &= 0.63 \end{aligned}$$

Now we can calculate V_s :

Eq 10.2-13

$$V_s = \left(\frac{V_s}{V_R} \right) * Q^{1,24} * A * 3630$$

$$= (0.63) * (0.95 \text{ inch}) * (10.23 \text{ acre}) * (3,630 \text{ ft}^3/\text{inch-acre})$$

$$= 22,225 \text{ ft}^3$$

Steps to Design Wet Detention Pond

4

Design channel protection (CP_v) orifice

Orifice sized to release CP_v over 24 hours

Orifice Equation:

$$Q_{CP_v} \text{ (cfs)} = C_D * A \text{ (ft}^2\text{)} * \sqrt{(2g)\Delta H_{\max} \text{ (ft)}}$$

Eq 10.4.3-3

$$(.257 \text{ cfs}) = (0.6) * (A) * \sqrt{2 * (32.2 \text{ ft/s}^2) * (1.28 \text{ ft})}$$

$$A = 0.047 \text{ ft}^2$$

$$D = \sqrt{4 * (0.047 \text{ ft}^2) / \pi}$$

$$D = 0.25 \text{ ft} = 2.9 \text{ in (use 3 inches for constructability)}$$

Q_{wq_v} (orifice flow rate) = 22,225 ft³ / 24 hr = .257 cfs

C_D (orifice coefficient) = 0.6

A = orifice area (ft²)

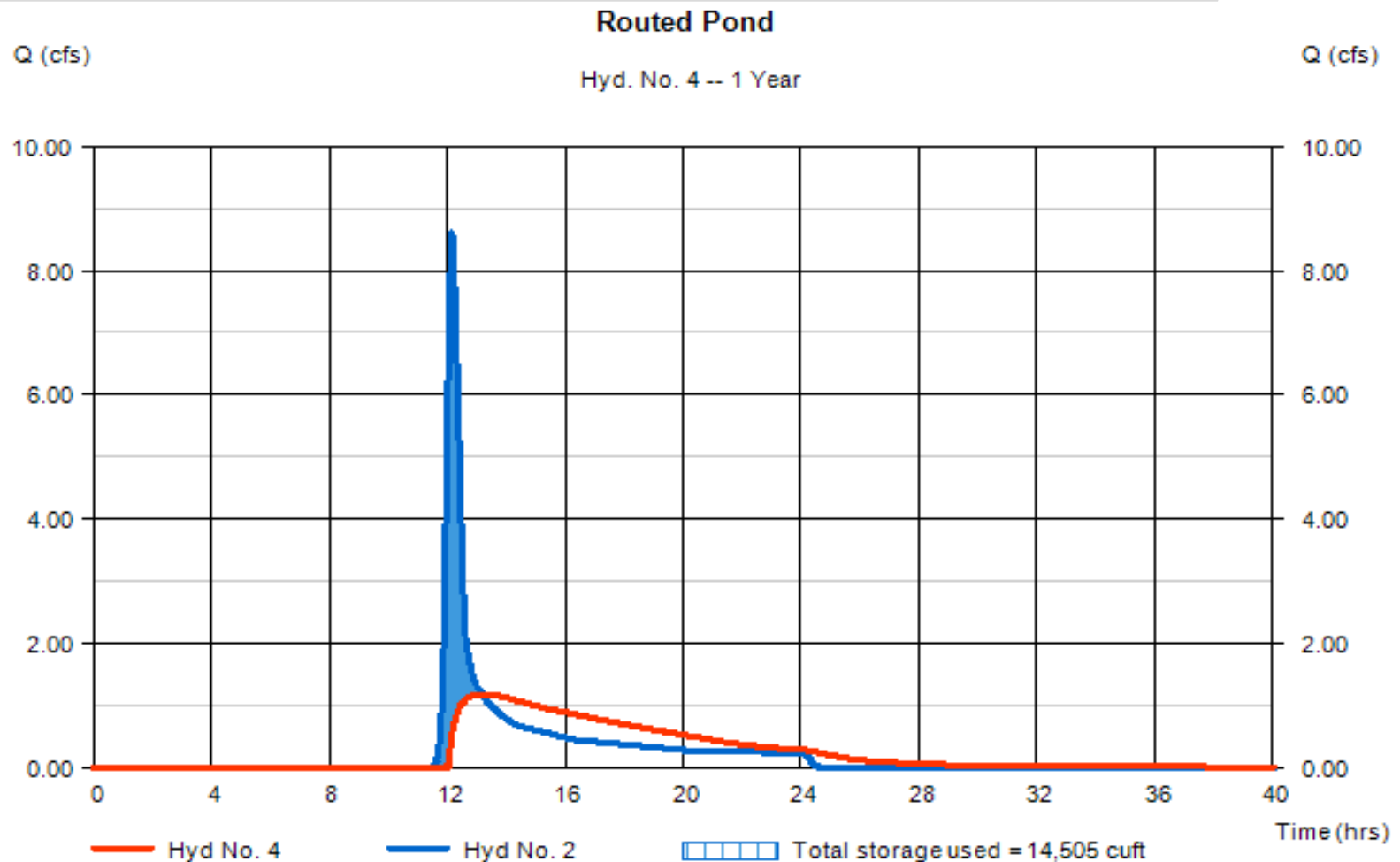
ΔH_{\max} (max depth at CP_v stage) = 1.28 ft

CP_v orifice: 3" diameter at top of water quality volume

Steps to Design Wet Detention Pond

4

Design channel protection (CP_V) orifice



Steps to Design Wet Detention Pond

1

Calculate forebay volume

$$V_{fbay} = 900 \text{ ft}^3$$

2

Calculate permanent pool volume and verify pond can maintain

$$V_{pool} = 900 \text{ ft}^3, \text{Depth}_{min} = 1.5 \text{ ft}$$

3

Calculate water quality volume and design orifice

$$WQ_v = 9,059 \text{ ft}^3, D_{orif} = 2'', \text{Elev}_{orif} = \text{perm pool elevation}$$

4

Calculate channel protection volume and design orifice

$$CP_v = 22,225 \text{ ft}^3, D_{orif} = 3'', \text{Elev}_{orif} = \text{water quality elevation}$$

5

Design pond and outlet to maintain 25-yr pre-development peak flow

$$Q_{25pre} =$$

6

Design spillway to safely convey 100-yr post-development peak flow

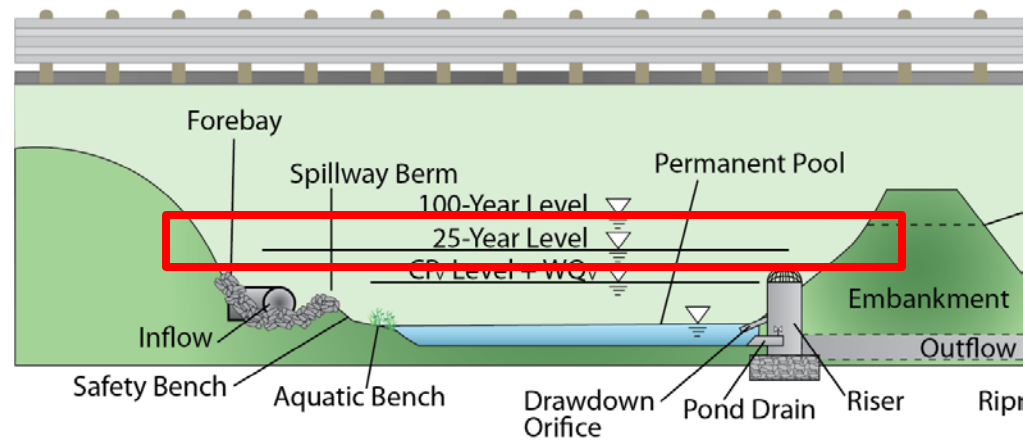
$$Q_{fpre} =$$

Steps to Design Wet Detention Pond

5 Maintain pre-development peak flows (Q_{p25})

Multi-step process to calculate Q_{p25} using NRCS TR-55 Methodology

- *Compute pre-development peak flow*
- *Compute post-development peak flow*
- *Calculate estimated storage volume*
- *Design outlet control structure for $Q_{25post} \leq Q_{25pre}$*



Overbank Flooding Protection Volume (Q_v) Calculation Steps

1

Determine runoff depth(Q -inches) for 25-year 24-hour storm event

2

Determine the unit peak discharge rate (q_u) for the 25-year 24-hour storm event

3

Compute the overbank flooding protection volume

4

Estimate the peak flow rates

Overbank Flooding Protection Volume (Q_v) Calculation Steps

1

Determine runoff depth (Q -inches) for 25-year 24-hour storm event

2

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3

Compute the overbank flooding protection volume

4

Estimate the peak flow rates

Calculate direct runoff: $Q''_{25,24} = \frac{(P - 0.2S)^2}{(P + 0.8S)}$ Eq 10.2-10

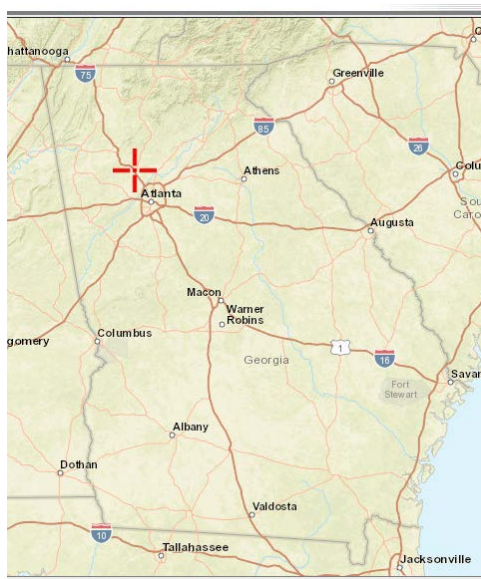
$$S = \frac{1000}{CN} - 10$$

$CN_{\text{exist}} = 61$ $S_{\text{pre}} = 6.4$ $P_{25,24} = ?$
 $CN_{\text{prop}} = 70$ $S_{\text{post}} = 4.3$

Overbank Flooding Protection Volume (Q_v) Calculation Steps

Obtain 25-year 24-hour rainfall depth for project location from NOAA website:

http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=ga



PDS-based precipitation frequency estimates with 90% confidence intervals (in inches) ¹									
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30-min	1.04 (0.889-1.23)	1.19 (1.02-1.41)	1.46 (1.24-1.72)	1.69 (1.43-2.01)	2.05 (1.67-2.51)	2.33 (1.86-2.88)	2.64 (2.02-3.32)	2.97 (2.17-3.80)	3.43 (2.39-4.48)
60-min	1.35 (1.15-1.59)	1.54 (1.32-1.82)	1.89 (1.61-2.23)	2.19 (1.85-2.60)	2.65 (2.17-3.24)	3.02 (2.40-3.73)	3.42 (2.61-4.29)	3.84 (2.80-4.92)	4.44 (3.10-5.80)
2-hr	1.66 (1.42-1.94)	1.90 (1.63-2.22)	2.32 (1.98-2.72)	2.69 (2.29-3.17)	3.25 (2.68-3.95)	3.71 (2.98-4.54)	4.19 (3.24-5.23)	4.72 (3.48-5.99)	5.45 (3.86-7.05)
3-hr	1.86 (1.61-2.17)	2.13 (1.83-2.48)	2.60 (2.23-3.03)	3.01 (2.57-3.53)	3.62 (3.00-4.38)	4.13 (3.33-5.03)	4.66 (3.62-5.78)	5.23 (3.89-6.60)	6.03 (4.30-7.76)
6-hr	2.30 (1.99-2.66)	2.61 (2.26-3.03)	3.16 (2.72-3.66)	3.63 (3.12-4.23)	4.33 (3.62-5.19)	4.91 (3.99-5.92)	5.51 (4.33-6.76)	6.15 (4.63-7.69)	7.04 (5.10-8.97)
12-hr	2.85 (2.48-3.27)	3.22 (2.80-3.70)	3.85 (3.34-4.44)	4.40 (3.80-5.08)	5.19 (4.35-6.15)	5.82 (4.77-6.95)	6.48 (5.14-7.87)	7.17 (5.47-8.86)	8.12 (5.96-10.2)
24-hr	3.41 (2.99-3.89)	3.88 (3.40-4.43)	4.66 (4.06-5.33)	5.31 (4.61-6.09)	6.23 (5.25-7.29)	6.94 (5.73-8.20)	7.67 (6.14-9.21)	8.41 (6.49-10.3)	9.41 (7.01-11.7)
2-day	3.93 (3.46-4.45)	4.52 (3.97-5.12)	5.47 (4.80-6.21)	6.26 (5.47-7.13)	7.35 (6.23-8.52)	8.18 (6.81-9.58)	9.02 (7.29-10.7)	9.86 (7.70-11.9)	11.0 (8.30-13.5)

Overbank Flooding Protection Volume (Q_v) Calculation Steps

1

Determine runoff depth (Q -inches) for 25-year 24-hour storm event

2

Determine the unit peak discharge rate (q_u) for the 25-year 24-hour storm event

3

Compute the overbank flooding protection volume

4

Estimate the peak flow rates

Calculate direct runoff: $Q''_{25,24} = \frac{(P - 0.2S)^2}{(P + 0.8S)}$ Eq 10.2-10

$$S = \frac{1000}{CN} - 10$$

$$CN_{\text{exist}} = 61$$

$$CN_{\text{prop}} = 70$$

$$S_{\text{pre}} = 6.4$$

$$S_{\text{post}} = 4.3$$

$$P_{25,24} = 6.23 \text{ inches}$$

$$Q_{25,24 \text{ pre}} = 2.15 \text{ inches}$$

$$Q_{25,24 \text{ NET}} = 0.83 \text{ inches}$$

$$Q_{25,24 \text{ post}} = 2.98 \text{ inches}$$

Overbank Flooding Protection Volume (Q_v) Calculation Steps

1

Determine runoff depth (Q -inches) for 25-year 24-hour storm event

2

Determine the unit peak discharge rate (q_u) for the 25-year 24-hour storm event

3

Compute the overbank flooding protection volume

4

Estimate the peak flow rates

Calculate direct runoff: $Q''_{25,24} = \frac{(P - 0.2S)^2}{(P + 0.8S)}$ Eq 10.2-10

$S = \frac{1000}{CN} - 10$ CN_{exist} = 61 S_{pre} = 6.4 P_{25,24} = 6.23 inches
CN_{prop} = 70 S_{post} = 4.3

$Q_{25,24 \text{ pre}} = 2.15 \text{ inches}$ $Q_{25,24 \text{ post}} = 2.98 \text{ inches}$

$Q_{25,24 \text{ NET}} = 0.83 \text{ inches}$

Determine q_u using Figure 10.2-8

Overbank Flooding Protection Volume (Q_v) Calculation Steps

Determine q_u :

Fig 10.2-8

$$Ia_{pre} = 0.2 * S_{pre} = 1.28$$

$$Ia_{post} = 0.2 * S_{post} = 0.86$$

$$P = 6.23 \text{ inches}$$

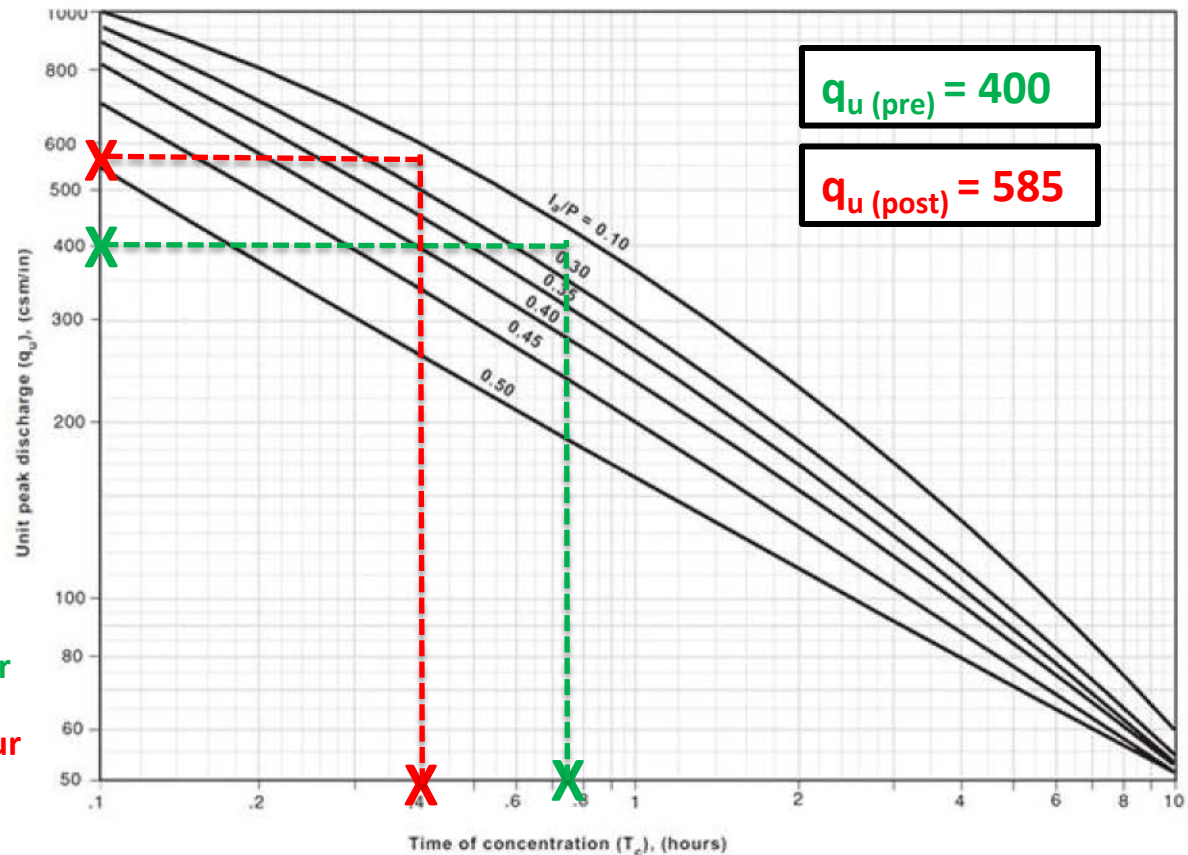
$$Ia/P_{(pre)} = 1.28/6.23 = 0.20$$

$$Ia/P_{(post)} = 0.868/6.23 = 0.14$$

$$Tc_{(pre)} = 45 \text{ minutes} = 0.75 \text{ hour}$$

$$Tc_{(post)} = 25 \text{ minutes} = 0.40 \text{ hour}$$

Figure 10.2-8 - Unit peak discharge (q_u) for SCS Type II rainfall distribution (10-33)



Overbank Flooding Protection Volume (Q_v) Calculation Steps

1

Determine runoff depth (Q -inches) for 25-year 24-hour storm event

Calculate direct runoff: $Q''_{25,24} = \frac{(P - 0.2S)^2}{(P + 0.8S)}$ Eq 10.2-10

$S = \frac{1000}{CN} - 10$

$CN_{\text{exist}} = 61$

$S_{\text{pre}} = 6.4$

$P_{25,24} = 6.23$ inches

$CN_{\text{prop}} = 70$

$S_{\text{post}} = 4.3$

$Q_{25,24 \text{ pre}} = 2.15$ inches

$Q_{25,24 \text{ post}} = 2.98$ inches

$Q_{25,24 \text{ NET}} = 0.83$ inches

Determine q_u using Figure 10.2-8

$q_{u \text{ 25,24 pre}} = 400$

$q_{u \text{ 25,24 post}} = 585$

3

Compute the overbank flooding protection volume

4

Estimate the peak flow rates

Overbank Flooding Protection Volume (Q_v) Calculation Steps

1

Determine runoff depth (Q -inches) for 25-year 24-hour storm event

2

Determine the unit peak discharge rate (q_u) for the 25-year 24-hour storm event

3

Compute the overbank flooding protection volume

4

Estimate the peak flow rates

Calculate direct runoff: $Q''_{25,24} = \frac{(P - 0.2S)^2}{(P + 0.8S)}$ Eq 10.2-10

$S = \frac{1000}{CN} - 10$ CN_{exist} = 61 CN_{prop} = 70 S_{pre} = 6.4 S_{post} = 4.3 P_{25,24} = 6.23 inches

$Q_{25,24 \text{ pre}} = 2.15 \text{ inches}$ $Q_{25,24 \text{ post}} = 2.98 \text{ inches}$

$Q_{25,24 \text{ NET}} = 0.83 \text{ inches}$

Determine q_u using Figure 10.2-8

q_{u 25,24 pre} = 400 q_{u 25,24 post} = 585

Eq 10.2-13

Calculate V_s (storage volume required): $V_s = \left(\frac{V_s}{V_R} \right) * Q''_{25,24} * A * 3,630$

Overbank Flooding Protection Volume (Q_v) Calculation Steps

1

Determine runoff depth (Q -inches) for 25-year 24-hour storm event

2

Determine the unit peak discharge rate (q_u) for the 25-year 24-hour storm event

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Calculate direct runoff: $Q''_{25,24} = \frac{(P - 0.2S)^2}{(P + 0.8S)}$ Eq 10.2-10

$S = \frac{1000}{CN} - 10$ CN_{exist} = 61 CN_{prop} = 70 S_{pre} = 6.4 S_{post} = 4.3 P_{25,24} = 6.23 inches

$Q_{25,24 \text{ pre}} = 2.15 \text{ inches}$ $Q_{25,24 \text{ post}} = 2.98 \text{ inches}$

$Q_{25,24 \text{ NET}} = 0.83 \text{ inches}$

Determine q_u using Figure 10.2-8

q_{u 25,24 pre} = 400 q_{u 25,24 post} = 585

Eq 10.2-13

Calculate V_s (storage volume required): $V_s = \left(\frac{V_s}{V_R}\right) * Q''_{25,24} * A * 3,630$

Determine q_o/q_i from Figure 10.2-6

Overbank Flooding Protection Volume (Q_v) Calculation Steps

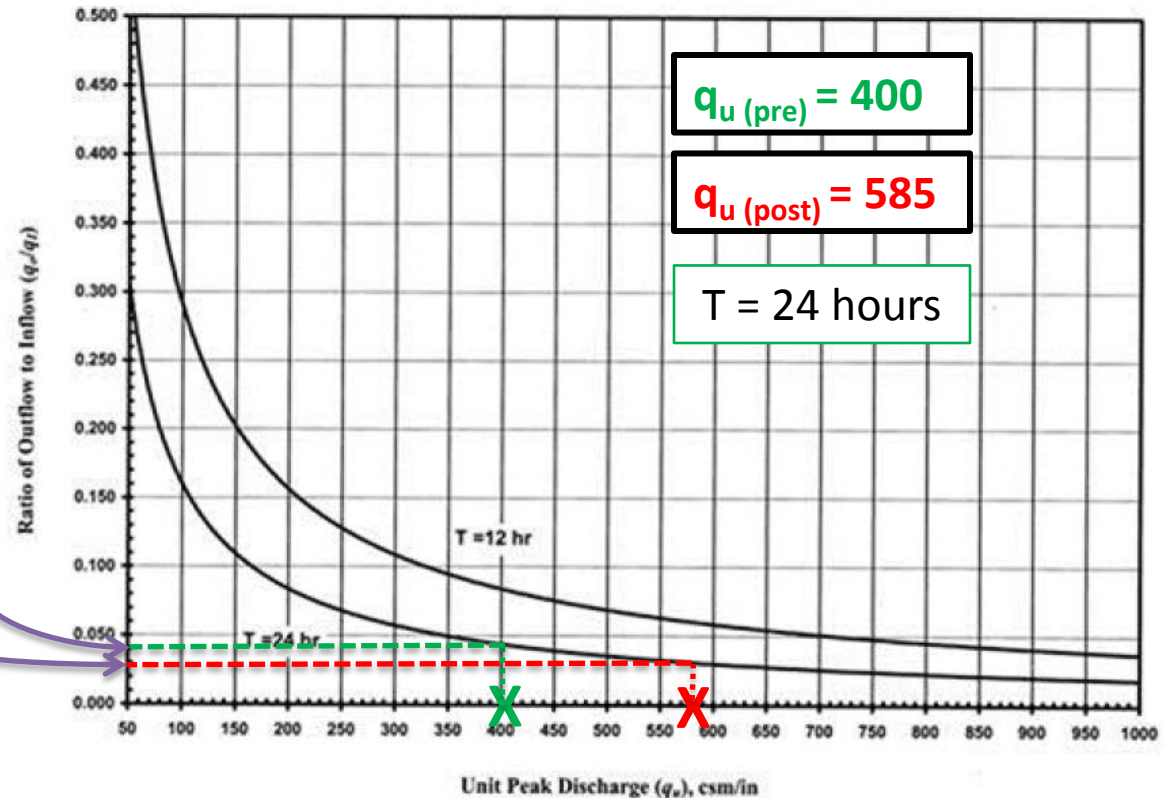
Determine q_o/q_i :

Figure 10.2-6 - SCS ratio of outflow to inflow curves (10-23)

Fig 10.2-8

$$q_o/q_i(\text{pre}) = .040$$

$$q_o/q_i(\text{post}) = .028$$



Overbank Flooding Protection Volume (Q_v) Calculation Steps

1

Determine runoff depth (Q -inches) for 25-year 24-hour storm event

Calculate direct runoff: $Q''_{25,24} = \frac{(P - 0.2S)^2}{(P + 0.8S)}$ Eq 10.2-10

$S = \frac{1000}{CN} - 10$ CN_{exist} = 61 S_{pre} = 6.4 P_{25,24} = 6.23 inches
CN_{prop} = 70 S_{post} = 4.3

2

Determine the unit peak discharge rate (q_u) for the 25-year 24-hour storm event

$Q_{25,24 \text{ pre}} = 2.15 \text{ inches}$ $Q_{25,24 \text{ post}} = 2.98 \text{ inches}$
 $Q_{25,24 \text{ NET}} = 0.83 \text{ inches}$

Determine q_u using Figure 10.2-8

q_{u 25,24 pre} = 400 q_{u 25,24 post} = 585

3

Compute the overbank flooding protection volume

Calculate V_s (storage volume required): $V_s = \left(\frac{V_s}{V_R} \right) * Q''_{25,24} * A *$

3,630

Determine q_o/q_i from Figure 10.2.6

q_o/q_{i 25,24 pre} = 0.040 q_o/q_{i 25,24 post} = 0.028

4

Estimate the peak flow rates

Eq 10.2-13

Overbank Flooding Protection Volume (Q_v) Calculation Steps

1

Determine runoff depth (Q -inches) for 25-year 24-hour storm event

Calculate direct runoff: $Q''_{25,24} = \frac{(P - 0.2S)^2}{(P + 0.8S)}$ Eq 10.2-10

$S = \frac{1000}{CN} - 10$ CN_{exist} = 61 S_{pre} = 6.4 P_{25,24} = 6.23 inches
CN_{prop} = 70 S_{post} = 4.3

$Q_{25,24 \text{ pre}} = 2.15 \text{ inches}$ $Q_{25,24 \text{ post}} = 2.98 \text{ inches}$
 $Q_{25,24 \text{ NET}} = 0.83 \text{ inches}$

2

Determine the unit peak discharge rate (q_u) for the 25-year 24-hour storm event

Determine q_u using Figure 10.2-8

$q_{u \text{ 25,24 pre}} = 400$ $q_{u \text{ 25,24 post}} = 585$

Eq 10.2-13

Calculate V_s (storage volume required): $V_s = \left(\frac{V_s}{V_R}\right) * Q''_{25,24} * A * 3,630$

Determine q_o/q_i from Figure 10.2.6

$q_o/q_{i \text{ 25,24 pre}} = 0.040$ $q_o/q_{i \text{ 25,24 post}} = 0.028$

Determine V_s/V_R from Equation 10.2-12:

$$\frac{V_s}{V_R} = 0.682 - 1.43 \left(\frac{q_o}{q_i}\right) + 1.64 \left(\frac{q_o}{q_i}\right)^2 - 0.804 \left(\frac{q_o}{q_i}\right)^3$$
 Eq 10.2-12
 $V_s/V_{R \text{ pre}} = 0.627$ $V_s/V_{R \text{ post}} = 0.643$

3

Compute the overbank flooding protection volume

4

Estimate the peak flow rates

Overbank Flooding Protection Volume (Q_v) Calculation Steps

1

Determine runoff depth (Q -inches) for 25-year 24-hour storm event

Calculate direct runoff: $Q''_{25,24} = \frac{(P - 0.2S)^2}{(P + 0.8S)}$ Eq 10.2-10

$S = \frac{1000}{CN} - 10$ CN_{exist} = 61 S_{pre} = 6.4 P_{25,24} = 6.23 inches
CN_{prop} = 70 S_{post} = 4.3

$Q_{25,24 \text{ pre}} = 2.15 \text{ inches}$ $Q_{25,24 \text{ post}} = 2.98 \text{ inches}$
 $Q_{25,24 \text{ NET}} = 0.83 \text{ inches}$

2

Determine the unit peak discharge rate (q_u) for the 25-year 24-hour storm event

Determine q_u using Figure 10.2-8

q_{u 25,24 pre} = 400 q_{u 25,24 post} = 585

Eq 10.2-13

3

Compute the overbank flooding protection volume

Calculate V_s (storage volume required): $V_s = \left(\frac{V_s}{V_R}\right) * Q''_{25,24} * A * 3,630$

Determine q_o/q_i from Figure 10.2.6

q_o/q_{i 25,24 pre} = 0.040 q_o/q_{i 25,24 post} = 0.028

Determine V_s/V_R from Equation 10.2-12:

$\frac{V_s}{V_R} = 0.682 - 1.43 \left(\frac{q_o}{q_i}\right) + 1.64 \left(\frac{q_o}{q_i}\right)^2 - 0.804 \left(\frac{q_o}{q_i}\right)^3$ Eq 10.2-12

$V_s/V_{R \text{ pre}} = 0.627$ $V_s/V_{R \text{ post}} = 0.643$

V_{s pre} = 50,059 ft³ V_{s post} = 71,181 ft³

4

Estimate the peak flow rates

Overbank Flooding Protection Volume (Q_v) Calculation Steps

1

Determine runoff depth (Q -inches) for 25-year 24-hour storm event

Calculate direct runoff: $Q''_{25,24} = \frac{(P - 0.2S)^2}{(P + 0.8S)}$

Eq 10.2-10

$S = \frac{1000}{CN} - 10$

$CN_{\text{exist}} = 61$

$S_{\text{pre}} = 6.4$

$P_{25,24} = 6.23$ inches

$CN_{\text{prop}} = 70$

$S_{\text{post}} = 4.3$

$Q_{25,24 \text{ pre}} = 2.15$ inches

$Q_{25,24 \text{ post}} = 2.98$ inches

$Q_{25,24 \text{ NET}} = 0.83$ inches

2

Determine the unit peak discharge rate (q_u) for the 25-year 24-hour storm event

Determine q_u using Figure 10.2-8

$q_{u \text{ 25,24 pre}} = 400$

$q_{u \text{ 25,24 post}} = 585$

Eq 10.2-13

Calculate V_s (storage volume required): $V_s = \left(\frac{V_s}{V_R}\right) * Q''_{25,24} * A *$

3,630

Determine q_o/q_i from Figure 10.2.6

$q_o/q_{i \text{ 25,24 pre}} = 0.040$

$q_o/q_{i \text{ 25,24 post}} = 0.028$

3

Compute the overbank flooding protection volume

Determine V_s/V_R from Equation 10.2-12:

$$\frac{V_s}{V_R} = 0.682 - 1.43 \left(\frac{q_o}{q_i}\right) + 1.64 \left(\frac{q_o}{q_i}\right)^2 - 0.804 \left(\frac{q_o}{q_i}\right)^3$$

$V_s/V_{R \text{ pre}} = 0.627$

$V_s/V_{R \text{ post}} = 0.643$

$V_{s \text{ pre}} = 50,059 \text{ ft}^3$

$V_{s \text{ post}} = 71,181 \text{ ft}^3$

$V_{s \text{ NET}} = 71,181 - 50,059 = 21,122 \text{ ft}^3$

Estimate the peak flow rate using Equation 10.2-14:

$Q_{25} (\text{pre}) = q_u * A * Q'' * F_p = 400 * 10.23 \text{ acres} / 640 \text{ acre/mi}^2 * 2.15 \text{ inches} * 1 = 13.7 \text{ cfs}$

$Q_{25} (\text{post}) = q_u * A * Q'' * F_p = 585 * 10.23 \text{ acres} / 640 \text{ acre/mi}^2 * 2.98 \text{ inches} * 1 = 27.9 \text{ cfs}$

4

Estimate the peak flow rates

Extreme Flooding Protection Volume ($Q_{f-100yr}$) Calculation Steps

1

Determine runoff depth(Q -inches) for 100-year 24-hour storm event

Calculate direct runoff: $Q''_{100,24} = \frac{(P-0.2S)^2}{(P+0.8S)}$

Eq 10.2-10

$S = \frac{1000}{CN} - 10$

$CN_{exist} = 61$

$S_{pre} = 6.4$

$P_{100,24} = 7.67$ inches

$CN_{prop} = 70$

$S_{post} = 4.3$

$Q_{100,24 pre} = 3.19$ inches

$Q_{100,24 post} = 4.17$ inches

2

Determine the unit peak discharge rate (q_u) for the 100-year 24-hour storm event

Determine q_u using Figure 10.2-8

$q_{u 100,24 pre} = 405$

$q_{u 100,24 post} = 590$

Eq 10.2-13

Calculate V_s (storage volume required): $V_s = \left(\frac{V_s}{V_R}\right) * Q''_{25,24} * A * 3,630$

3

Compute the overbank flooding protection volume

Determine q_o/q_i from Figure 10.2.6

$q_o/q_{i 100,24 pre} = 0.037$

$q_o/q_{i 100,24 post} = 0.025$

Determine V_s/V_R from Equation 10.2-12:

$\frac{V_s}{V_R} = 0.682 - 1.43 \left(\frac{q_o}{q_i}\right) + 1.64 \left(\frac{q_o}{q_i}\right)^2 - 0.804 \left(\frac{q_o}{q_i}\right)^3$

$V_s/V_{R pre} = 0.631$

$V_s/V_{R post} = 0.647$

$V_{S pre} = 74,748$ ft³

$V_{S post} = 100,190$ ft³

Estimate the peak flow rate using Equation 10.2-14:

$Q_{100 (pre)} = q_u * A * Q'' * F_p = 405 * 10.23 \text{ acres} / 640 \text{ acre/mi}^2 * 3.19 \text{ inches} * 1 = 20.7 \text{ cfs}$

$Q_{100 (post)} = q_u * A * Q'' * F_p = 590 * 10.23 \text{ acres} / 640 \text{ acre/mi}^2 * 4.17 \text{ inches} * 1 = 39.3 \text{ cfs}$

4

Estimate the peak flow rates

Steps to Design Wet Detention Pond

1

Calculate forebay volume

$$V_{fbay} = 900 \text{ ft}^3$$

2

Calculate permanent pool volume and verify pond can maintain

$$V_{pool} = 900 \text{ ft}^3, \text{Depth}_{min} = 1.5 \text{ ft}$$

3

Calculate water quality volume and design orifice

$$WQ_v = 9,059 \text{ ft}^3, D_{orif} = 2", \text{Elev}_{orif} = \text{perm pool elevation}$$

4

Calculate channel protection volume and design orifice

$$CP_v = 22,225 \text{ ft}^3, D_{orif} = 3", \text{Elev}_{orif} = \text{water quality elevation}$$

5

Design pond and outlet to maintain 25-yr pre-development peak flow

$$Q_{25pre} =$$

6

Design spillway to safely convey 100-yr post-development peak flow

$$Q_{fpre} =$$

Storage Volume Estimation Steps

25-year Storm

1

Calculate ratio of post ($Q_{p25post}$) to pre-development (Q_{p25pre}) discharge:

2

Calculate the inflow volume of runoff (V_R)

3

Find the ratio of V_S/V_R using Figure 10.5-3

4

Calculate V_S

Storage Volume Estimation Steps

25-year Storm

1

Calculate ratio of post ($Q_{P25post}$) to pre-development (Q_{P25pre}) discharge:

Calculate $Q_{P25(pre)} / Q_{P25(post)}$:

$$\frac{Q_{P25(pre)}}{Q_{P25(post)}} = \left(\frac{13.7 \text{ cfs}}{27.9 \text{ cfs}} \right) = 0.49$$

2

Calculate the inflow volume of runoff (V_R)

3

Find the ratio of V_S/V_R using Figure 10.5-3

4

Calculate V_S

Storage Volume Estimation Steps

25-year Storm

1

Calculate ratio of post ($Q_{P25post}$) to pre-development (Q_{P25pre}) discharge:

2

Calculate the inflow volume of runoff (V_R)

3

Find the ratio of V_S/V_R using Figure 10.5-3

4

Calculate V_S

Calculate $Q_{P25(pre)} / Q_{P25(post)}$:

$$\frac{Q_{P25(pre)}}{Q_{P25(post)}} = \left(\frac{13.7 \text{ cfs}}{27.9 \text{ cfs}} \right) = 0.49$$

Calculate V_R :

$$\begin{aligned} V_R &= K_R * Q_D * A_M \\ &= (53.33) * (2.98 \text{ in}) * (10.23 \text{ ac}) * (\text{mi}^2/640 \text{ acre}) \\ &= 2.55 \text{ ac-ft} = 111,026 \text{ ft}^3 \end{aligned}$$

V_R = volume of runoff (ft^3)

K_R = conversion from in-mi^2 to acre-ft

$Q_D = Q_{25,24}$ = 25-yr, 24-hr runoff depth (in)

A_M = basin area (mi^2)

Storage Volume Estimation Steps

25-year Storm

1

Calculate ratio of post ($Q_{P25post}$) to pre-development (Q_{P25pre}) discharge:

2

Calculate the inflow volume of runoff (V_R)

3

Find the ratio of V_S/V_R using Figure 10.5-3

4

Calculate V_S

Calculate $Q_{P25(pre)} / Q_{P25(post)}$:

$$\frac{Q_{P25(pre)}}{Q_{P25(post)}} = \left(\frac{13.7 \text{ cfs}}{27.9 \text{ cfs}} \right) = 0.49$$

Calculate V_R :

$$\begin{aligned} V_R &= K_R * Q_D * A_M \\ &= (53.33) * (2.99 \text{ in}) * (10.23 \text{ ac}) * (\text{mi}^2/640 \text{ acre}) \\ &= 2.55 \text{ ac-ft} = 111,026 \text{ ft}^3 \end{aligned}$$

V_R = volume of runoff (ft^3)

K_R = conversion from in-mi^2 to acre-ft

$Q_D = Q_{1,24}$ = 1-yr, 24-hr runoff depth (in)

A_M = basin area (mi^2)

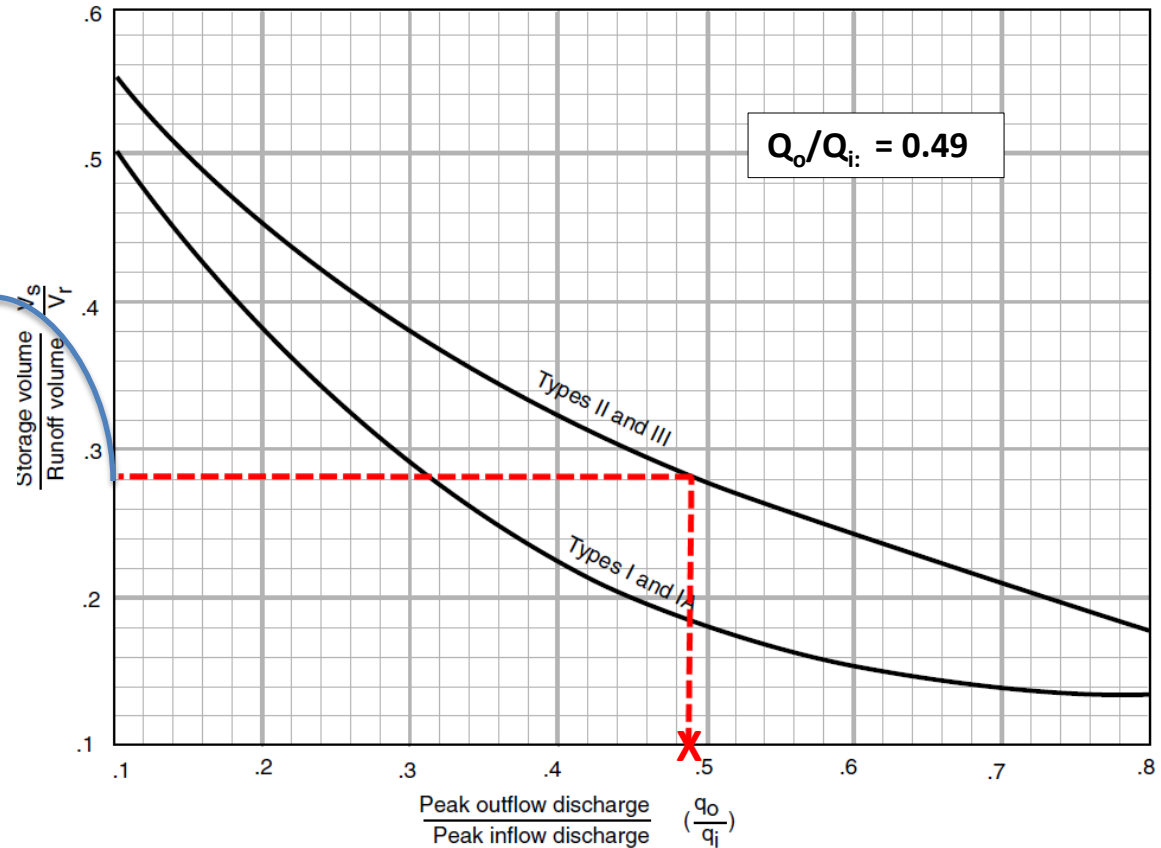
Find V_S/V_R :using Figure 10.5-3:

Steps to Design Wet Detention Pond

5 Maintain pre-development peak flows (Q_{p25})

- Find the ratio of V_S/V_R using Figure 10.5-3

$$V_S/V_R (25\text{-yr}) = 0.28$$



Storage Volume Estimation Steps

25-year Storm

1

Calculate ratio of post (Q_{post}) to pre-development (Q_{pre}) discharge:

Calculate $Q_{P25(\text{pre})} / Q_{P25(\text{post})}$:

$$\frac{Q_{P25(\text{pre})}}{Q_{P25(\text{post})}} = \left(\frac{13.7 \text{ cfs}}{27.9 \text{ cfs}} \right) = 0.49$$

2

Calculate the inflow volume of runoff (V_R)

Calculate V_R :

$$\begin{aligned} V_R &= K_R * Q_D * A_M \\ &= (53.33) * (2.99 \text{ in}) * (10.23 \text{ ac}) * (\text{mi}^2 / 640 \text{ acre}) \\ &= 2.55 \text{ ac-ft} = 111,026 \text{ ft}^3 \end{aligned}$$

V_R = volume of runoff (ft^3)

K_R = conversion from in-mi^2 to acre-ft

$Q_D = Q_{1,24}$ = 1-yr, 24-hr runoff depth (in)

A_M = basin area (mi^2)

3

Find the ratio of V_S/V_R using Figure 10.5-3

Find V_S/V_R : using Figure 10.5-3:

$$V_S/V_R (25\text{-yr}) = 0.28$$

4

Calculate V_S

Storage Volume Estimation Steps

25-year Storm

1

Calculate ratio of post (Q_{post}) to pre-development (Q_{pre}) discharge:

2

Calculate the inflow volume of runoff (V_R)

3

Find the ratio of V_S/V_R using Figure 10.5-3

4

Calculate V_S

Calculate $Q_{P25(pre)} / Q_{P25(post)}$:

$$\frac{Q_{P25(pre)}}{Q_{P25(post)}} = \left(\frac{13.7 \text{ cfs}}{27.9 \text{ cfs}} \right) = 0.49$$

Calculate V_R :

$$\begin{aligned} V_R &= K_R * Q_D * A_M \\ &= (53.33) * (2.99 \text{ in}) * (10.23 \text{ ac}) * (\text{mi}^2/640 \text{ acre}) \\ &= 2.55 \text{ ac-ft} = 111,026 \text{ ft}^3 \end{aligned}$$

V_R = volume of runoff (ft^3)

K_R = conversion from in-mi^2 to acre-ft

$Q_D = Q_{1,24}$ = 1-yr, 24-hr runoff depth (in)

A_M = basin area (mi^2)

Find V_S/V_R :using Figure 10.5-3:

$$V_S/V_R (25\text{-yr}) = 0.28$$

Calculate V_S :

$$\begin{aligned} V_S &= V_R * V_S/V_R \\ &= (111,026 \text{ ft}^3) * (0.28) \\ &= 31,087 \text{ ft}^3 \end{aligned}$$

Steps to Design Wet Detention Pond

1

Calculate forebay volume

$$V_{\text{fbay}} = 900 \text{ ft}^3$$

2

Calculate permanent pool volume and verify pond can maintain

$$V_{\text{pool}} = 900 \text{ ft}^3, \text{Depth}_{\text{min}} = 1.5 \text{ ft}$$

3

Calculate water quality volume and design orifice

$$\text{WQ}_v = 9,059 \text{ ft}^3, D_{\text{orif}} = 2'', \text{Elev}_{\text{orif}} = \text{perm pool elevation}$$

4

Calculate channel protection volume and design orifice

$$\text{CP}_v = 22,225 \text{ ft}^3, D_{\text{orif}} = 3'', \text{Elev}_{\text{orif}} = \text{water quality elevation}$$

5

Design pond and outlet to maintain 25-yr pre-development peak flow

$$Q_{25} = 31,087 \text{ ft}^3$$

6

Design spillway to safely convey 100-yr post-development peak flow

Storage Volume Estimation Steps

100-year Storm

1

Calculate ratio of post ($Q_{f100\text{post}}$) to pre-development ($Q_{100\text{pre}}$) discharge:

Calculate $Q_{f100(\text{pre})} / Q_{f100(\text{post})}$:

$$\frac{Q_{P100(\text{pre})}}{Q_{100(\text{post})}} = \left(\frac{20.7 \text{ cfs}}{39.3 \text{ cfs}} \right) = 0.53$$

2

Calculate the inflow volume of runoff (V_R)

Calculate V_R :

$$\begin{aligned} V_R &= K_R * Q_D * A_M \\ &= (53.33) * (4.17 \text{ in}) * (10.23 \text{ ac}) * (\text{mi}^2/640 \text{ acre}) \\ &= 3.55 \text{ ac-ft} = \mathbf{154,843 \text{ ft}^3} \end{aligned}$$

V_R = volume of runoff (ft^3)

K_R = conversion from in-mi² to acre-ft

$Q_D = Q_{1,24}$ = 100-yr, 24-hr runoff depth (in)

A_M = basin area (mi²)

3

Find the ratio of V_S/V_R using Figure 10.5-3

Find V_S/V_R :using Figure 10.5-3:

$$V_S/V_R (100\text{-yr}) = 0.26$$

4

Calculate V_S

Calculate V_S :

$$\begin{aligned} V_S &= V_R * V_S/V_R \\ &= (154,843 \text{ ft}^3) * (0.26) \\ &= \mathbf{40,259 \text{ ft}^3} \end{aligned}$$

Design Example

Steps to Design Wet Detention Pond

1

Calculate forebay volume

$$V_{\text{fbay}} = 900 \text{ ft}^3$$

2

Calculate permanent pool volume and verify pond can maintain

$$V_{\text{pool}} = 900 \text{ ft}^3, \text{Depth}_{\text{min}} = 1.5 \text{ ft}$$

3

Calculate water quality volume and design orifice

$$\text{WQ}_v = 9,059 \text{ ft}^3, D_{\text{orif}} = 2", \text{Elev}_{\text{orif}} = \text{perm pool elevation}$$

4

Calculate channel protection volume and design orifice

$$\text{CP}_v = 22,225 \text{ ft}^3, D_{\text{orif}} = 3", \text{Elev}_{\text{orif}} = \text{water quality elevation}$$

5

Design pond and outlet to maintain 25-yr pre-development peak flow

$$Q_{\text{P25}} = 31,087 \text{ ft}^3$$

6

Design spillway to safely convey 100-yr post-development peak flow

$$Q_f = 40,259 \text{ ft}^3$$

Caution: Manual calculations are approximate and can result in storage volumes larger than necessary. Route using software that bases calculations on entire hydrograph rather than just peak flow, for more accurate storage design

Steps to Design Wet Detention Pond

5 Maintain pre-development peak flows (Q_{p25})

Calculate Storage Volume Required using NRCS Method

Pre-Project
Conditions

CN = 61

Tc = 45 min

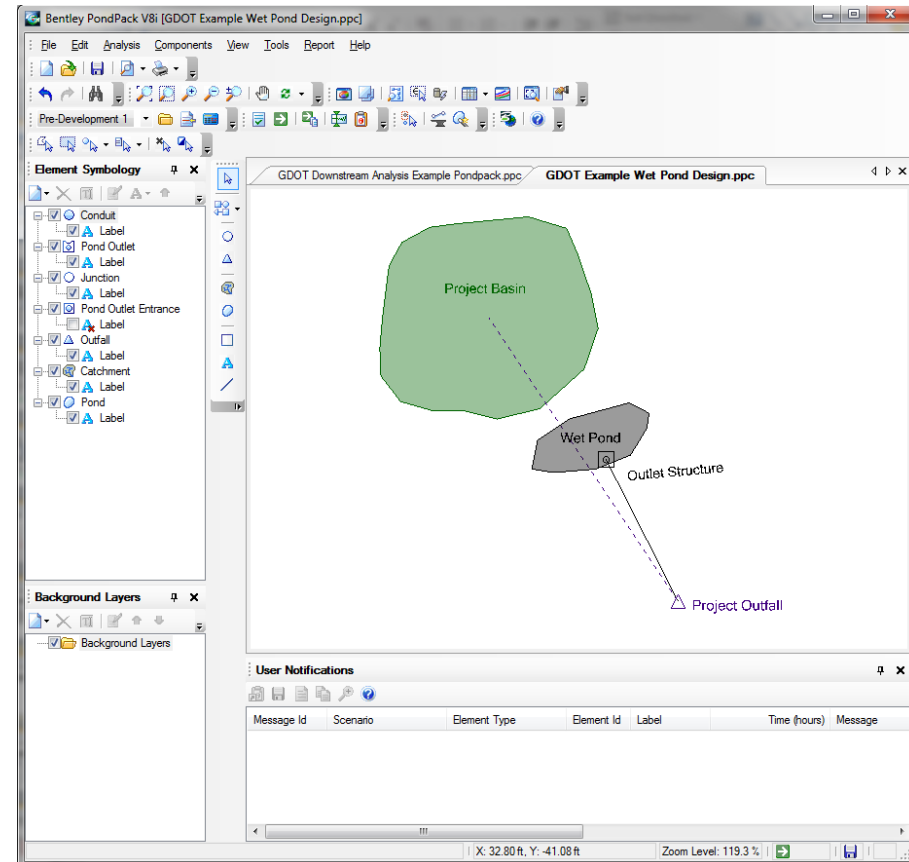
Properties - Catchment - Project Basin (30)

Project Basin

SCS Unit Hydrograph Method (Predefined)

ID	30
Label	Project Basin
Notes	
GIS-IDs	<Collection: 0 items>
Hyperlinks	<Collection: 0 items>
<Geometry>	
Active Topology	
Catchment	
Outflow Node	Project Outfall
Rainfall	
Runoff	
Runoff Method	Unit Hydrograph
Loss Method	SCS CN
Use Scaled Area?	False
Area (User Defined) (acres)	10.230
CN Input Type	Simple CN
SCS CN	61.000
Unit Hydrograph Method	SCS Unit Hydrograph
Tc Input Type	User Defined Tc
Time of Concentration (hours)	0.750
Time of Concentration (Composite) (hours)	0.750

Time of Concentration (hours)



Steps to Design Wet Detention Pond

5 Maintain pre-development peak flows (Q_{p25})

Calculate Storage Volume Required using NRCS Method

**Pre-Project
Conditions**

**CN = 61
Tc = 45 min**

Properties - Catchment - Project Basin (30)

Project Basin 100%

SCS Unit Hydrograph Method (Predefined)

<General>

ID	30
Label	Project Basin
Notes	
GIS-IDs	<Collection: 0 items>
Hyperlinks	<Collection: 0 items>

<Geometry>

Active Topology

Catchment

Rainfall

Runoff

Unit Hydrograph (Advanced)

Results

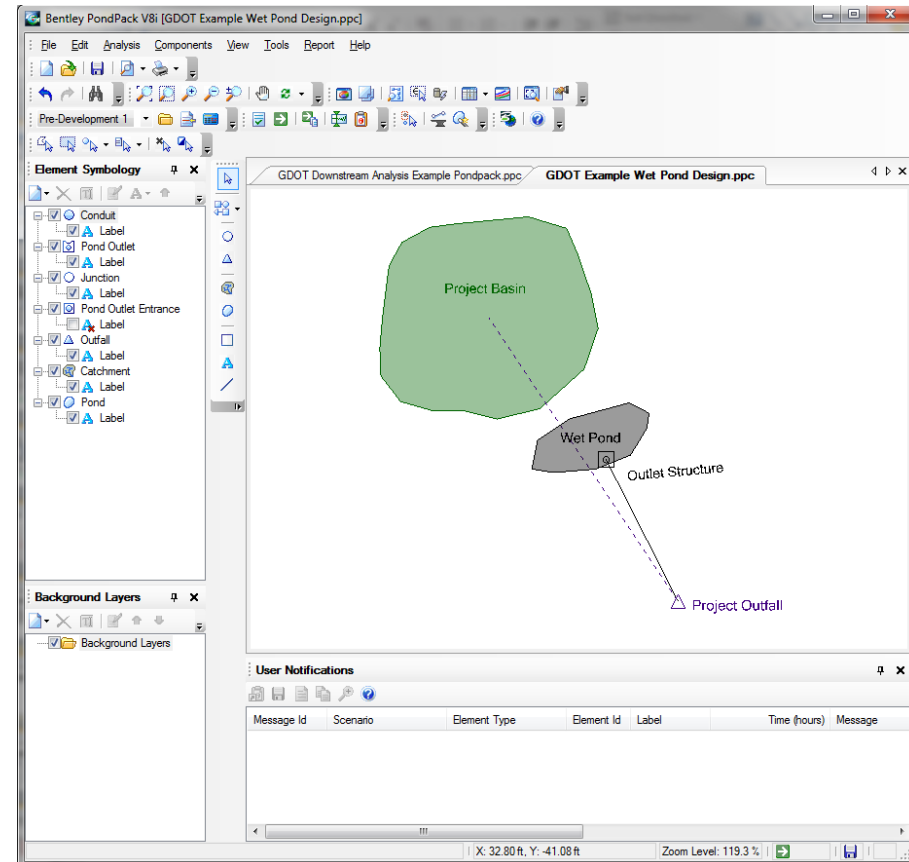
Results (Computed)

Computational Time Increment (hours)	0.100
Flow (Peak, Computed) (ft ³ /s)	13.81
Time to Peak (Computed) (hours)	12.400

Results (Interpolated)

Results (SCS Unit Hydrograph)

Results (Computed)



Steps to Design Wet Detention Pond

5 Maintain pre-development peak flows (Q_{p25})

Calculate Storage Volume Required using NRCS Method

Post-Project
Conditions

Roadway
Impervious
Area Added

CN = 70
Tc = 25 min

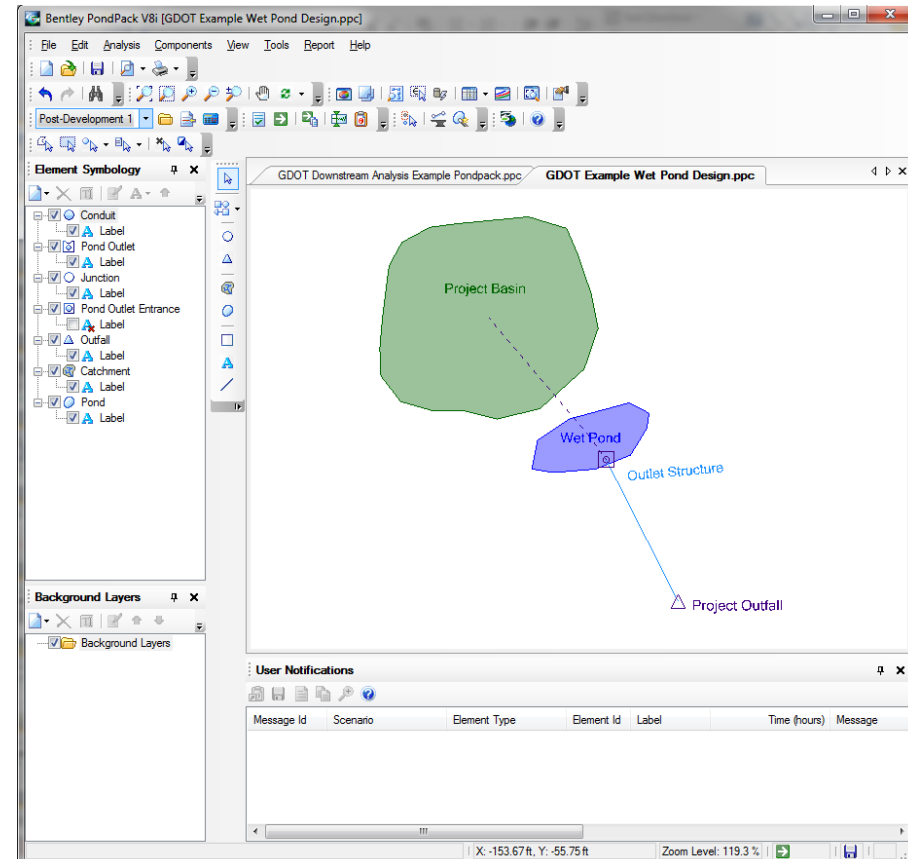
Properties - Catchment - Project Basin (30)

Project Basin 100%

SCS Unit Hydrograph Method (Predefined)

ID	30
Label	Project Basin
Notes	
GIS-IDs	<Collection: 0 items>
Hyperlinks	<Collection: 0 items>
<Geometry>	
Active Topology	
Catchment	
Outflow Node	Wet Pond
Rainfall	
Runoff	
Runoff Method	Unit Hydrograph
Loss Method	SCS CN
Use Scaled Area?	False
Area (User Defined) (acres)	10.230
CN Input Type	Simple CN
SCS CN	70.000
Unit Hydrograph Method	SCS Unit Hydrograph
Tc Input Type	User Defined Tc
Time of Concentration (hours)	0.420
Time of Concentration (Composite) (hours)	0.420

Time of Concentration (hours)



Steps to Design Wet Detention Pond

5 Maintain pre-development peak flows (Q_{p25})

Calculate Storage Volume Required using NRCS Method

Post-Project
Conditions

Roadway
Impervious
Area Added

CN = 70
Tc = 25 min

Properties - Catchment - Project Basin (30)

Project Basin

SCS Unit Hydrograph Method (Predefined)

<General>

ID	30
Label	Project Basin
Notes	
GIS-IDs	<Collection: 0 items>
Hyperlinks	<Collection: 0 items>

<Geometry>

Active Topology

Catchment

Rainfall

Runoff

Unit Hydrograph (Advanced)

Results

Results (Computed)

Computational Time Increment (hours)	0.067
Flow (Peak, Computed) (ft ³ /s)	26.44
Time to Peak (Computed) (hours)	12.200

Results (Interpolated)

Results (SCS Unit Hydrograph)

Results (Computed)

Bentley PondPack V8i [GDOT Example Wet Pond Design.ppc]

File Edit Analysis Components View Tools Report Help

Post-Development 1

Element Symbology

GDOT Downstream Analysis Example Pondpack.ppc GDOT Example Wet Pond Design.ppc

Project Basin

Wet Pond

Outlet Structure

Project Outfall

Background Layers

User Notifications

Message Id	Scenario	Element Type	Element Id	Label	Time (hours)	Message

X: -153.67 ft, Y: -55.75 ft Zoom Level: 119.3 %

Steps to Design Wet Detention Pond

5 Maintain pre-development peak flows (Q_{p25})

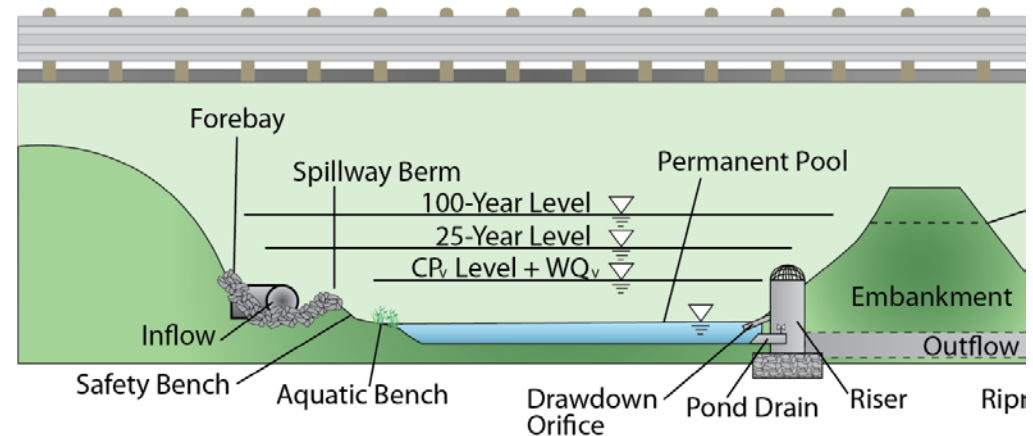
Comparison of peak flows calculated with software:

Scenario	Peak Flow (cfs)		
	1-yr	25-yr	100-yr
Pre-development	2.47	13.95	21.34
Post-development	8.61	29.52	41.62
Difference	6.14	15.57	16.11
Percent Increase	248%	112%	95%

Wet Detention Pond Design

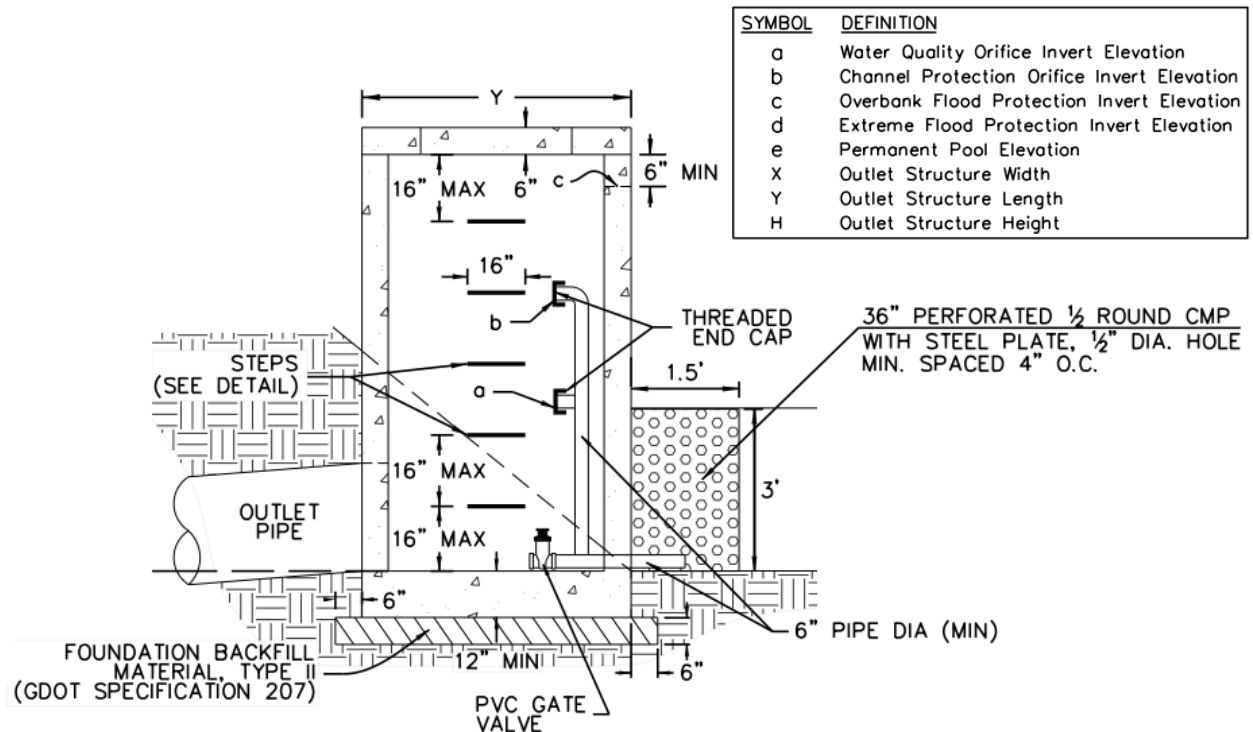
Estimate dimensions of wet detention basin:

- Use software OR manual calculation
- Dimensions will need adjustment to include:
 - Permanent Pool
 - Safety bench
 - Aquatic Bench



Wet Detention Pond Design

- Design emergency spillway to provide safe passage of the 100-yr, 24-hr event

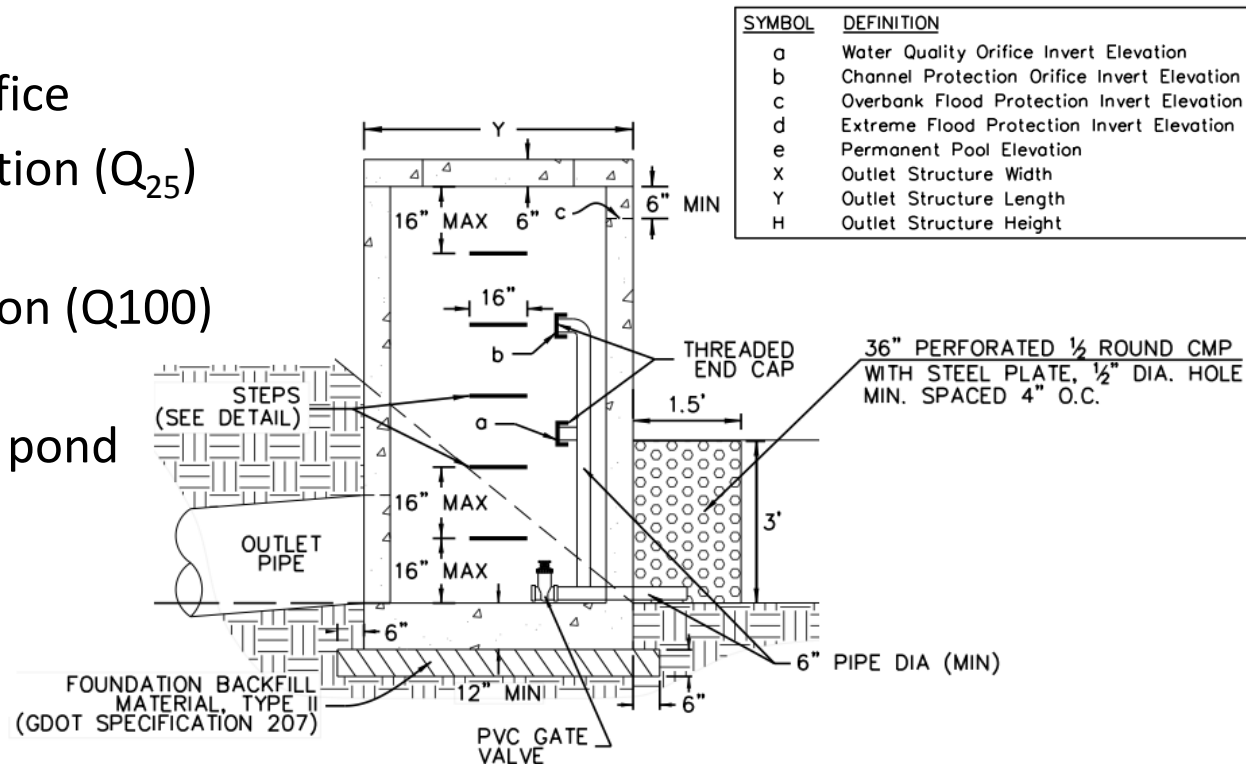


Detailed Wet Pond Design

Outlet Structure Configuration

Configure Outlet Structure According to Calculations:

- Outlet pipe
- Water Quality Orifice
- Channel Protection Orifice
- Overbank Flood Protection (Q_{25}) Weir/Orifice
- Extreme Flood Protection (Q_{100}) Weir/Orifice
- Emergency Spillway (in pond embankment)



Detailed Wet Pond Design

Pond Design

Routed pond outflows must maintain or be less than the 25-year pre-developed peak flow rate

☐ 1-Yr
 ☐ 2-Yr
 ☐ 3-Yr
 ☐ 5-Yr
 ☐ 10-Yr
 ☒ 25-Yr
 ☐ 50-Yr
 ☐ 100-Yr

Hyd. No.	Hydrograph type	Peak flow	Time interval	Time of conc. Tc	Time to peak	Volume	Inflow hyd(s)	Maximum Elevation	Maximum Storage	Hydrograph description
	(origin)	(cfs)	(min)	(min)	(min)	(cuft)		(ft)	(cuft)	
1	SCS Runoff	13.95	2	45.00	742.00	79,530				Pre-dev
2	SCS Runoff	29.52	2	25.00	728.00	109,255				Post-dev
3										
4	Reservoir	13.88	2		746.00	107,790	2	105.73	41,826	Routed Pond

Detailed Wet Pond Design

Pond Design

Must provide 1' (minimum) of freeboard for 100-yr event:

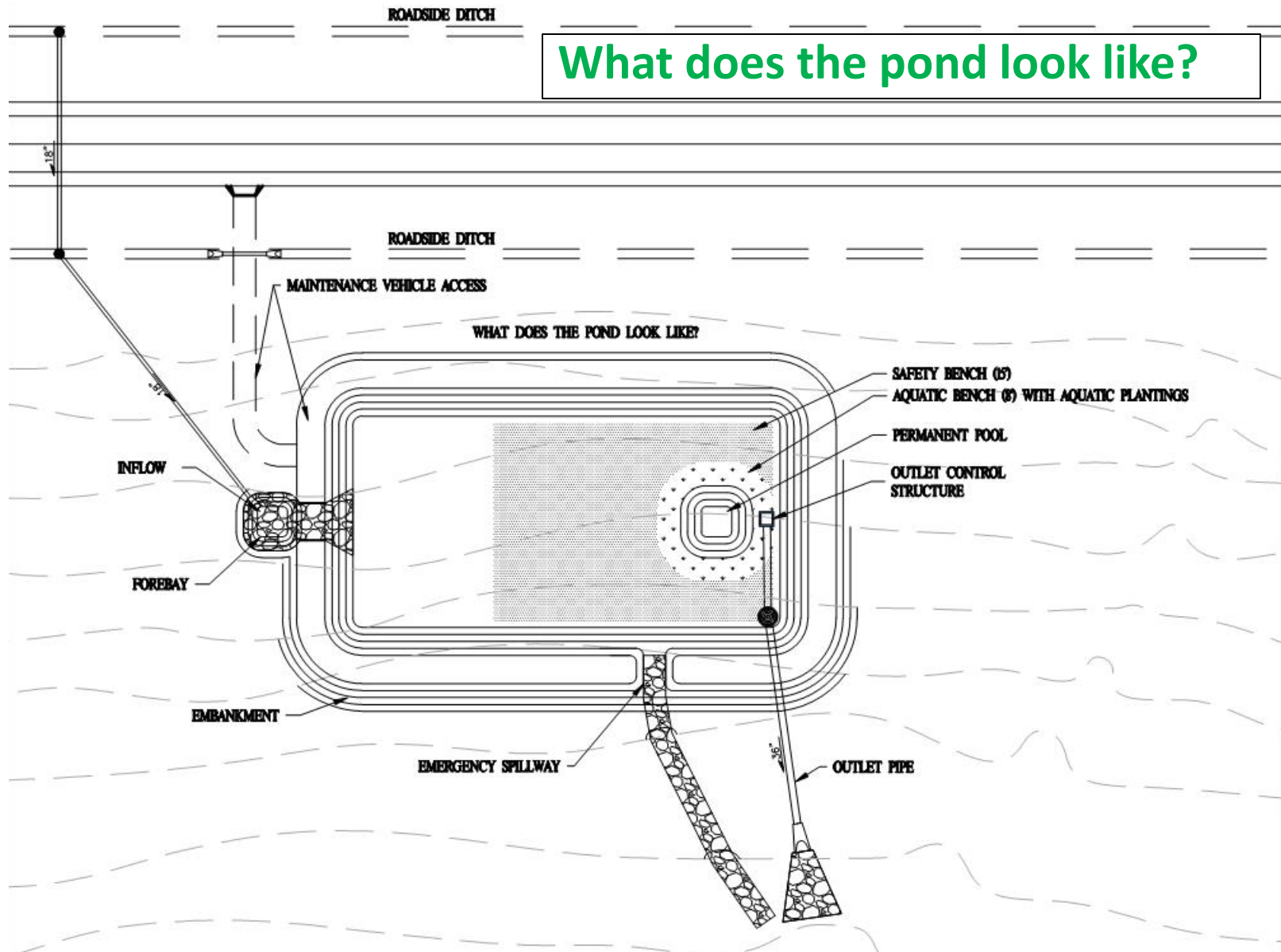
- 100-yr pond elevation = 106.24 + 1.00 (freeboard)
= 107.24

- **Set top of pond embankment at 108.00 for constructability**

<input type="radio"/> 1-Yr <input type="radio"/> 2-Yr <input type="radio"/> 3-Yr <input type="radio"/> 5-Yr <input type="radio"/> 10-Yr <input type="radio"/> 25-Yr <input type="radio"/> 50-Yr <input checked="" type="radio"/> 100-Yr										
Hyd. No.	Hydrograph type	Peak flow	Time interval	Time of conc. Tc	Time to peak	Volume	Inflow hyd(s)	Maximum Elevation	Maximum Storage	Hydrograph description
	(origin)	(cfs)	(min)	(min)	(min)	(cuft)		(ft)	(cuft)	
1	SCS Runoff	21.34	2	45.00	742.00	117,591				Pre-dev
2	SCS Runoff	41.62	2	25.00	728.00	152,874				Post-dev
3										
4	Reservoir	24.84	2		742.00	151,409	2	106.24	52,126	Routed Pond

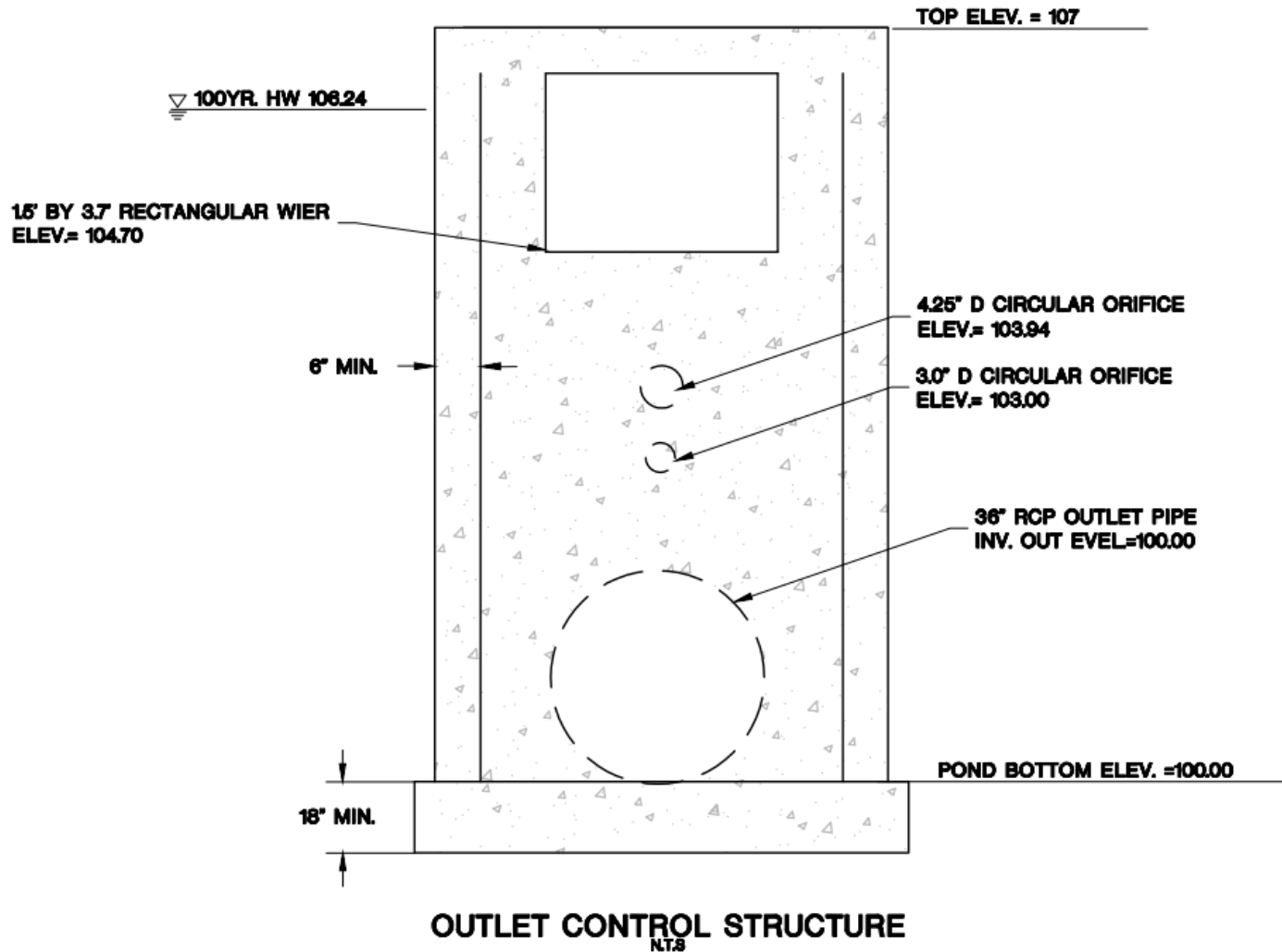
Detailed Wet Pond Design

What does the pond look like?



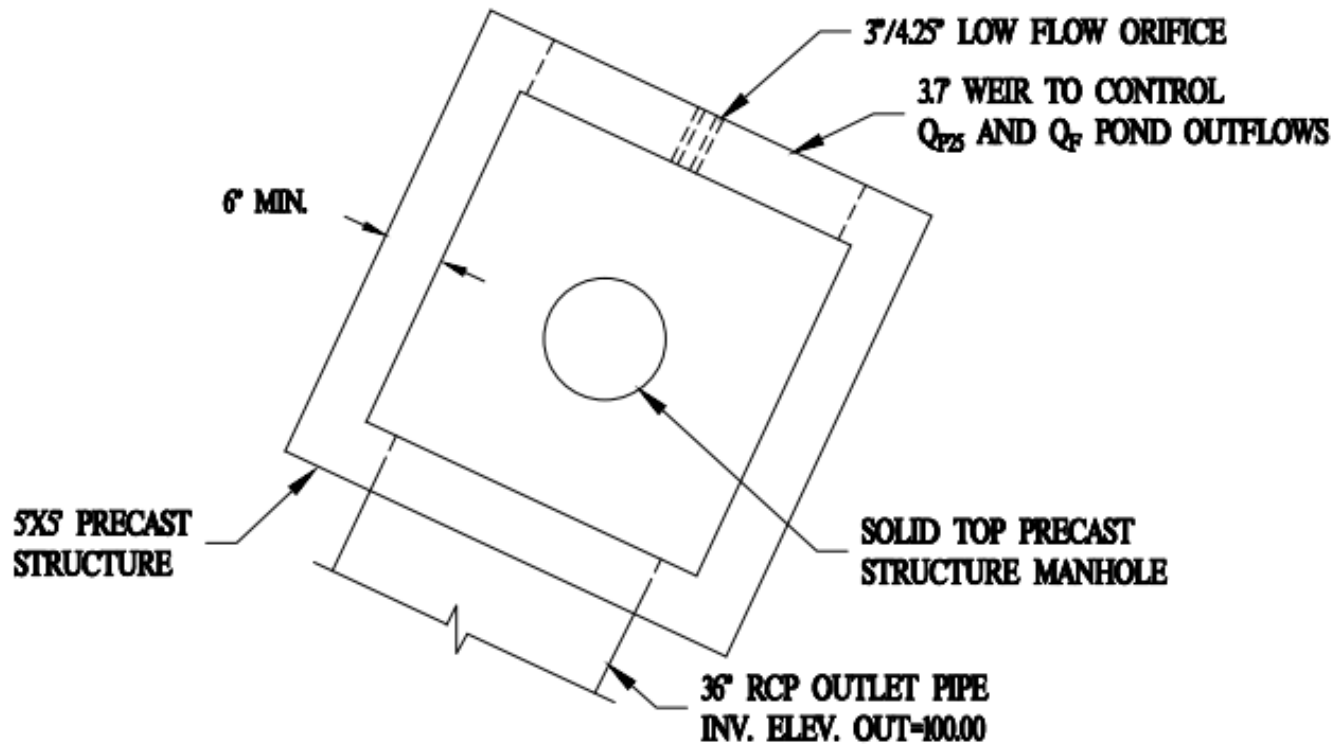
Detailed Wet Pond Design

What does the OCS look like?



Detailed Wet Pond Design

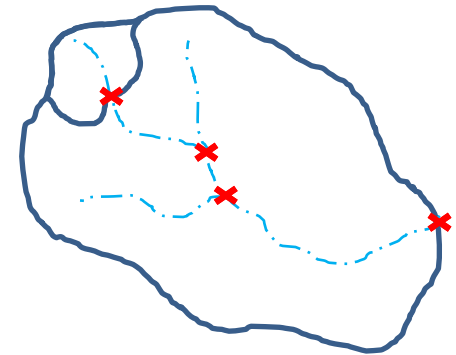
What does the OCS look like?



PLAN
NTS

Design Example - Other Considerations

- Finally, perform cost analysis **\$\$\$**
 - May be infeasible due to cost
- Perform a downstream analysis
 - Remember detention is required if downstream analysis shows adverse impacts due to increased flows, even if it is determined infeasible based on MS4 infeasibility criteria
- Other considerations:
 - OCS buoyancy calculation
 - Construction detailing
 - Construction notes
 - Special provisions



Questions



Brad McManus, PE

MS4 Program Manager

Office of Design Policy and Support

bmcmanus@dot.ga.gov